EVERYDAY PROBLEMS IN SCIENCE

PIEPER AND BEAUCHAMP

Francis M. Jones

Wilma B. Uncapher
Georgetown
Colo.
Jan. 24, 1928

Property of
John Uncapher
Roggen
Colo

120

100

463

423

Start text on page 17.

94108

272

Wilma Uncapher
Jan. 24, 1928

EVERYDAY PROBLEMS IN SCIENCE

By

CHARLES JOHN PIEPER

HEAD OF THE DEPARTMENT OF NATURAL SCIENCE, UNIVERSITY OF CHICAGO HIGH SCHOOL

and

WILBUR LEE BEAUCHAMP

INSTRUCTOR IN NATURAL SCIENCE, UNIVERSITY OF CHICAGO HIGH SCHOOL—INSTRUCTOR IN EDUCATION, COLLEGE OF EDUCATION, UNIVERSITY OF CHICAGO

SCOTT, FORESMAN AND COMPANY

CHICAGO ATLANTA NEW YORK

268.4

DEDICATION

To the students whose interest and enthusiasm in science have made the preparation of this course of study such a pleasant and worthwhile enterprise, and to the students who, through a study of this book, will become better citizens of their communities.

GENERAL PREFACE

For the past six years the writer has been closely associated with the authors of the teaching enterprise of which the present volume is the outcome. He has watched them formulate their objectives, organize and recast their material, try out and discard one device in the technique of teaching after another—all in the presence of the most impartially critical of audiences: a succession of boys and girls who learn or do not learn according as we succeed or fail as teachers. The experimental organization of a course requires patience; if it does not work satisfactorily this year, we can forthwith form our hypotheses touching the cause of failure; but we must wait a year before we can experiment further. Such has been the history of the development of this text.

The mission of the older textbooks in science was apt to be the teaching of principles which were or were not, as fate decreed, applied to the interpretation of the environment. Education was confounded with erudition, and the more a boy knew, the better educated he was presumed to be. The general science movement interprets its task to be that of helping the younger generation to understand the world in which it finds itself. We accordingly do not teach principles and then apply them: we teach the child about the world, and in the process certain of the fundamental principles of science come to be definite realities. The center of effort, however, is the child and his adjustment, and not knowledge for its own sake.

The authors have been singularly diligent in their adherence to this guidance. The environment is presented in some seventeen units, embracing the principal aspects in which it is manifested in the common life of society. Attention is focused

upon the understanding of the world in each of these aspects. The pupil is first taken up into a high place and shown the scene as a whole, not as a syllabus or table of contents, but as a coherent and comprehensible picture. The process is repeated for each of the seventeen units and for each of the major phases of each unit. Each unit can be understood by the pupil in terms of its concrete meaning to his own life and to that of the society of which he is a part. This is very different from beginning with a definition of physics or chemistry and thence pursuing the presentation in the logical order of development of the science. It is different too from a series of chapters describing natural phenomena and their meaning, capable of being read, and memorized if you will, but not capable of producing any modification of the pupil's attitude toward his world except in casual instances.

Successful learning in this or in any related field implies not only the acquisition of new concepts and the attainment of new attitudes, but it implies the inclination to seek farther and the ability to do so. The essence of educating an American citizen is to set him going under his own power and point him right. In a word, successful teaching results in the development of ability to study and the discovery of intellectual interest.

The backbone of the text is therefore the exercises provided for study. Rightly understood, these are not directions for study, but the media in which directed study can be done and in which the kind of study ability which is specific to the sciences can grow. If the text were simply descriptive and explanatory material interestingly illustrated, it would doubtless be valuable for reading purposes but scarcely worthwhile for assigning class meetings or for paying teachers to work with. The teacher and the descriptive pages are essential to the learning process, but understanding and insight appear only as the result of hard study, prolonged study, and well directed study.

The test of learning is: what will the pupil of his own initiative do with it? Accordingly, the exercises throughout are their own testing, and the ultimate test is furnished in the voluntary supplementary projects listed for each unit. If the pupil elects to work at these projects as he has opportunity, we have perhaps the best possible evidence that the course is establishing in him the new attitudes which are not only the ultimate test of learning but are learning itself.

Henry C. Morrison.

The University of Chicago, 1925

AUTHORS' PREFACE
AND
FOREWORD TO TEACHERS

The contributions of science study to present-day life are so manifold and important that we have come to speak of this age as the age of science. Everywhere, in the home, the school, the playground, the workshop, and the community in general, the phenomena and applications of science influence our lives. Citizens of today can better understand, enjoy, appreciate, and control their environment, and adjust themselves to it, through knowledge of the science involved in the daily problems of sensible, happy, healthful, comfortable, and efficient living. Their intellectual, moral, and ethical character depends in part upon their understanding of and their attitude toward the forces and materials of nature.

Our boys and girls grow up in this scientific age and become the citizens of the next generation. At the adolescent period their natural interest in the environment creates a desire and a demand to know something of the great contributions of science to modern life and to human progress; their near approach to adult citizenship makes the need for science knowledge and for correct attitudes toward science problems imperative. They must be acquainted with and have training in the proper methods of thinking about such problems, so that they may be able to do such thinking for themselves.

The immediate aim of science instruction in the years following the elementary school period is, therefore, the broadening of the youth's experiences with the forces and materials of his environment and the developing of an attitude of open-mindedness and a spirit of inquiry concerning the nature, value, and use of science in modern life. Along with this experience-getting and attitude-forming come the power and inclination to do effectively what civilization demands of every citizen.

And out of these results grow the appreciation of nature and the cultural and enjoyment values which help to build individuality and character. The ultimate aim of introductory science is, then, the active and wholesome participation in the desirable activities of life, or good citizenship. If science instruction in the early years of high school meets this objective, it will in an equal degree meet the objective of exploring the fields of science, and will thereby stimulate and guide the student in his later study.

The formulation of the course of study in science for the adolescent youth is a difficult task. Such a course must attain the aims stated in the preceding paragraph. The subject-matter and the method of study must appeal to the student. The knowledge and training involved must be worthwhile and usable in daily life. Careful selection from a wide field of knowledge must be made. The content must be organized for an actual study or teaching situation. The method of presentation must conform to the best modern practice. Only by trial and error in the classroom can all of these criteria be met.

We, the authors, have thoroughly tested the study material in this book in the light of valid criteria. Since 1913 we have been associated in science classrooms with students of the adolescent age. Their interests, needs, and abilities have been carefully studied. Available educational literature and actual practice bearing on science instruction have been thoroughly examined and observed.

Eight years ago we began to formulate mimeographed study material for use in the classroom. Each year since that time the material has been revised according to the valid criticisms arising during its use. A considerable number of other teachers in the department and in other schools have assisted in this work. Many secondary-school administrators and teachers of science have visited our classes and have offered numerous criticisms and suggestions for improvement. Particular assistance has been given by the hundreds of science

teachers who have been students in our teacher-training courses during the eight-year period.

In the selection of subject-matter four major points have been constantly before us:

First, the subject-matter must be based upon past experiences of boys and girls and must broaden their knowledge of the environment. Knowledge which will result in an adjustment to the environment will necessarily emphasize the hygienic aspects of daily life. Reference to the table of Contents will show how this principle of selection has been kept in mind throughout the course. Second, these materials must satisfy the student's natural interests in the phenomena and applications of science. Thousands of questions by students, various investigations of their interests made by different educators, and, above all, daily association with a large number of classes over a period of years have assisted in meeting this second criterion. Third, the subject-matter must be of the proper degree of difficulty. The ability of the students thoroughly to understand the content of the course under classroom conditions has been, therefore, a guiding principle. This requires a degree of difficulty which insures a proper demand on the student's power of thinking as well as the satisfaction which comes through successful accomplishment of the activities involved. Fourth, the organization of the materials for teaching purposes and the consequent method of study must give training in proper methods of study in order to develop desirable attitudes, correct study habits, high ideals, wholesome interests, and worthwhile perspectives.

The selection of subject-matter for a course is no more important than the organization and presentation of such subject-matter for training students. During the years of experimentation on the course presented in this text many plans of organization have been tested. The result of the classroom experimentation has led us to organize the content into relatively few units, each unit representing a major topic or problem of everyday social significance. With such a plan

students approach and see the facts and principles of science in their proper environmental relations, and use only such facts and principles as are necessary to solve the major problems of their surroundings. The artificial distinctions between special sciences as organized by specialists are of little consequence in the life of the average citizen and are, therefore, postponed to later elective courses in science.

The number of units is small. This is in accord with the recommendations of several recent committees on introductory science courses. Experimentation has shown that such a plan eliminates the piecemeal memoriter type of learning which resulted when the course was divided into many chapters or units, and provides instead a medium for the understanding of worthwhile phases of the environment through more extended and more thorough study of the relationships of the science facts involved. Moreover, tests have proved that even the facts and principles of science are better remembered when studied as a part of a major problem. The small number of units has, therefore, been decided upon to afford real training value and to eliminate the encyclopedic treatment of science.

While the content of the various units is arranged in a sequential order of development which gives the student a story of his environment, it is well to think of each unit as a "block of study." Essentially the book is a study-book. Each unit is constructed in such way that the laws of learning and of problem-solving are used. This plan of organization demands that the treatment be full enough to cover the gaps so common in an encyclopedic treatment of science. The study of a considerable amount of related material is the only sure way to arrive at a thorough understanding of a problem.

The PRELIMINARY EXERCISES which precede each unit furnish concrete means for recall of past experiences and knowledge pertinent to the new unit. At the same time they review units previously studied in so far as the knowledge is necessary in the new topic or problem. Such recall and review

motivate the work and are in accord with the important principle of proceeding from the known to the unknown. The exercises are so stated that each student can test himself in writing and thereby furnish the teacher with a diagnostic measure of his students' residue of knowledge before they proceed further in the unit. With such diagnosis the teacher may know which points to emphasize in the later study and may also properly fit the course to the individual student.

A Story of the Unit follows the Preliminary Exercises. This brief sketch of the unit content covers only a few pages. It gives the pupil a bird's-eye-view of the unit, emphasizing the development of man's knowledge in the particular topic, his dependence upon the understanding of that topic, and his use of such understanding. Moreover, it further motivates his later study and assists him in relating the less important details of the problems which follow to the central idea of the unit. Experimentation has shown that the story serves its purpose best if presented by the teacher in a short, clear talk of from 10 to 20 minutes.

With the proper motivation and with an over-view of the unit in mind, the pupil next turns to a careful, *detailed* study of the important problems into which the unit is naturally subdivided in daily life. Here he is provided with many activities which broaden his knowledge and give him training in the proper study attitudes and in the methods of solving problems. Throughout the problems he finds various exercises, planned not only to recall usable experiences and to acquire new ones, but also to test his understanding of the reading and of the experiments performed during his study.

The content of the problems is so planned that either the individual or the group method of instruction may be used. The exercises may be done by individual pupils or used as a basis for class discussion and quiz. In either case they give training and practice in such important activities as: (*a*) oral or written expression, (*b*) silent reading, (*c*) interpretation of the printed page, (*d*) interpretation of experiments, (*e*) inter-

pretation of maps, diagrams, tables, or graphs, (*f*) preparing outlines, (*g*) summarizing knowledge, (*h*) reorganizing knowledge for new purposes, (*i*) drawing, (*j*) finding information in source material, and (*k*) studying home and shop appliances.

These activities thus furnish abundant opportunity for correlation of the work in science with courses in English, mathematics, drawing, civics, and manual or domestic art. Since each kind of activity appears in several different parts of the course, there will result the value of practice and repetition in correct methods of performing such activities.

Especial attention has been given throughout the text to the experiments and illustrations. The materials and apparatus for the experiments have been selected so that the small school as well as the large school will have no difficulty in securing them. The Teacher's Guide-Book contains suggestions for many alternative experiments. An unusually large number of illustrations to which the text makes constant reference has been included. In order to insure the study of these illustrations, exercises have been formulated which require the students to make careful analyses of them.

In order to provide for individual differences of interest and ability there are ADDITIONAL EXERCISES AND PROJECTS placed at the end of each unit. At the end of the text proper there are lists of TOPICS AND PROJECTS FOR INVESTIGATION and REFERENCES for each unit. The ADDITIONAL EXERCISES AND PROJECTS are of such nature that the better students can do them with little or no further study beyond the unit content. The TOPICS AND PROJECTS FOR INVESTIGATION represent subjects which are related to the unit, but which will require considerable study or experimentation beyond the subject-matter of the unit. The REFERENCES will suggest extended source material for further study. The best references for the TOPICS AND PROJECTS FOR INVESTIGATION are given after each topic or project. The teacher may shorten the course here outlined by judicious elimination of some of the numerous exercises. On the other hand, the course may be extended

by the inclusion of as many of the Additional Exercises and Projects or of the Topics and Projects for Investigation as may seem desirable. The list of references is intentionally made very long to assure that some of the books given may be found in any library. Selected lists with publishers' names and prices will be found in the Teacher's Guide-Book.

On page xxiii will be found a section To the Student. This section contains a brief story of the entire course. It also includes directions on "How to Study This Book." These will assist the student to understand the "how and why" of each step in his study, thus making his various activities purposeful. The teacher should not fail to direct his students to read this section carefully before beginning the study of Unit I. Detailed instructions and suggestions to the teacher will be found in the Teachers' Guide-Book, which may be obtained from the publishers.

The pronunciation of all difficult words and of proper names is given in the Pronunciation List beginning on page 575. It is urged that the teachers encourage in the students the habit of using the List and of pronouncing all terms correctly. The pronunciations are given according to Webster's Dictionary.

Charles J. Pieper
Wilbur L. Beauchamp

ACKNOWLEDGMENTS

Space does not permit us to express our grateful appreciation to each of the large number of critics of the manuscript of this book. We trust that it will not be invidious, therefore, if we here thank the few who have given most during the years of experimentation involved in a task made pleasant by their encouragement and assistance. Our first debt is to Mr. Charles H. Judd, Director of the School of Education of the University of Chicago, and to Mr. W. C. Reavis, Principal, University High School, for the opportunity presented. Particular gratitude is felt for the constant guidance and assistance of Mr. H. C. Morrison, Superintendent of the Laboratory Schools, who has given most freely of his time and energy during the last six years and who has made possible the conditions of the experiment during the most important stages of the development of the materials.

To the following who have read the final manuscript of this book we are glad to express our thanks, but they are in no sense to be held responsible for the content or plan: Miss Katherine Neumayer, East High School, Aurora, Illinois, Mr. Daniel R. Campbell, Stuyvesant High School, New York City, Mr. Rae G. Van Cleve, Fairfax High School, Los Angeles, California, Mr. W. Kiang, University of Wisconsin, Mr. James G. Pentz, Director of Inspection of High Schools, State of Pennsylvania, Mr. George J. Baltzar, Washington High School, Milwaukee, Wisconsin. Our thanks are also due Dr. Arthur J. Cramp of the American Medical Association, who read the proofs of Unit VII, and Mr. Storrs B. Barrett of Yerkes Observatory for his critical reading of Unit I.

The illustrations are important and essential. We are indebted to many organizations and institutions for these.

Finally, we wish to remember our own teachers of previous years, who have caused us to retain an interest in the education of boys and girls even above our interest in any special science.

C. J. P.
W. L. B.

CONTENTS

UNIT IV: OBTAINING A GOOD WATER SUPPLY

UNIT V: KEEPING IN GOOD PHYSICAL CONDITION

UNIT VI: SELECTING AND CARING FOR OUR CLOTHING

UNIT VII: PROTECTING OURSELVES FROM DISEASE

UNIT VIII: THE NATURE AND CONTROL OF FIRE

UNIT IX: PROVIDING HEAT AND FRESH AIR IN OUR BUILDINGS

UNIT X: MATERIALS FOR CONSTRUCTION

UNIT XI: MACHINES FOR DOING WORK

UNIT XII: PUTTING THE FORCES OF AIR AND WATER TO WORK

UNIT XIII: USING STEAM AND EXPLODING GAS FOR POWER

UNIT XIV: GENERATING AND USING ELECTRICITY

UNIT XV: LIGHTING OUR BUILDINGS AND STREETS

TO THE STUDENT

Nature holds many interesting secrets. Some of these you learn by observing what goes on around you; others you read about or hear discussed from time to time; many you can never hope to know unless you study science. Until you have studied the science of nature (natural science), you will be ignorant of the wonderful forces and materials which nature has provided for your education, your comfort, your enjoyment, and your well-being. Like the primitive man of old or the savage of today, you can have only ignorance, fear, and strange superstitions about your surroundings. With a knowledge of science and the scientific way of thinking about life, you will come to know, enjoy, and appreciate nature, and therefore be a happier and better member of your home and community.

This book will, if you use it properly, acquaint you with some forces and materials of nature and, at the same time, show you how to think about your surroundings in a scientific way. The story of the "things" to be studied and the method you will use are stated in Sections (*A*) and (*B*) following.

(*A*) THE STORY OF THIS BOOK

Imagine, for a moment, that you are living centuries ago when man knew little about the earth and its place among the heavenly bodies. The shape, size, and movements of the earth are unknown to you. The causes of day and night and the seasons have not been explained. The changes in weather and their causes, as well as the climate of your region, are puzzles; perhaps man has not even tried to understand them. You and your neighbors spend the days providing food and seeking ways to protect yourselves against the weather, climate, beasts, fire, and other men. You live on raw food and know

little or nothing about cultivating the soil. Your water supply is obtained from springs or streams. There is no knowledge of how to keep in good health. The cause of disease and methods of protecting yourself from disease have not been considered. Present-day clothing and building materials do not exist. Machinery for farming and factory use has not been invented; there are no farms or factories. The use of fire for manufacturing materials such as iron, steel, cement, and glass, is yet undiscovered. Dwellings, such as they are, are neither heated nor lighted. The many conveniences and devices in your present-day home are lacking.

"What a strange world!" you say. It does seem strange to one who has known only the world of the twentieth century. Yet, for centuries man lived in such primitive conditions. All sorts of strange imaginings and notions were his. As the years passed, however, he began to understand nature better. Being able to see, hear, smell, taste, feel, and, above all, to think and to reason with himself and his neighbors, he came to explain some of nature's wonders. Particularly during the last few centuries he has made great progress in his knowledge and use of the things which nature provides.

Today, because of the many discoveries and inventions, we live in an age of science. We know something of the place of the earth in the universe, its movements, and their effects. Climate and weather are understood, at least in part. A knowledge of farming allows us to produce a great variety of foods which we know how to select, prepare, cook, serve, and preserve in different ways. A purified water supply can be obtained and distributed to our buildings, and the dangerous wastes and sewage can be made harmless. The value to health of good food, pure water, fresh air, exercise, sleep, rest, and proper clothing is understood, and the causes and methods of prevention of many diseases have been discovered. Man has learned how to make use of such forces as fire, steam, air, water, electricity, heat, light, and sound. Various building materials, heating and cooking devices, lighting devices, ma-

chines, engines, electrical inventions, and methods of transportation and communication show further the great difference between the life of today and the life of years past.

The field of man's knowledge is so large that it would require many years to know thoroughly only one small portion of the science of your surroundings. You can, however, by a careful study of this book get a start into the secrets of science, and also develop an interest for the further study of some particular science in later years.

Let us get first a bird's-eye view of the earth on which we live and of what man has learned about some of the great forces and materials of nature. Look, now, through the table of Contents to see the titles of the different units, or major topics, which you will study. Then return to this story, keeping in mind that the following paragraphs give a picture of each unit. The paragraphs consider the units in the same order in which they are listed in the table of Contents.

The Earth on Which You Live is but a small part of the great Universe (Unit I). Thousands of stars are scattered in space. These stars are really enormous bodies millions and millions of miles from the earth. One of the stars, the nearest to the earth, is the sun—the center around which the earth and seven other planets revolve. The sun, planets, and moons are the principal members of the solar system, or sun's family. Of all these bodies the earth is most interesting to you because it is your home. Its forces and materials, and the heat and light from the sun, make life possible; its movements cause day and night, the seasons, changes in time, weather, and climate; the land, water, and air furnish you with the essentials and comforts for your daily existence.

While there are many forces and materials in your surroundings, perhaps no two forces are more important than Weather and Climate (Unit II). These determine where you live, what you eat, the clothes you wear, the kind of houses in which you live, your health, and, in fact, nearly everything you have and do. Favorable weather and climate have been,

since the earliest days of man's existence, two of the greatest factors in his progress. Climate and civilization appear to be closely related. Moreover, as man has learned to understand and predict weather changes and to know the climates of different regions, he has been able to live more comfortably and efficiently.

Your existence on the earth requires certain essential materials. PROVIDING A GOOD FOOD SUPPLY (Unit III) is one of our most important problems. Your food supply has always come from the green plants, which are the food factories of the earth. Whether you eat the plant products or the animals which feed on the plants, you must depend upon the plants for your daily menu. In early times man lived on raw plants and animals. He had no scientific way to select, prepare, cook, or preserve his food. As the centuries passed, he learned to make use of fire for cooking. A study of the composition of foods and the use which the body makes of the different kinds led to a knowledge of how to select that which is best to insure a healthy body. The cause of decay and scientific methods of preserving and transporting foods were also discovered.

Nature has furnished you with another essential for life. Without water you can live but a short time. OBTAINING A GOOD WATER SUPPLY (Unit IV) is another of man's great problems in life. Even in primitive times communities were established where nature provided springs or other sources of fresh water. Later, water was obtained from underground sources or from distant lakes and rivers. Today every community has as one of its most important problems that of furnishing its inhabitants with a plentiful and pure water supply. Pumps, reservoirs, pipes, faucets, and hydrants are now in use. The water used for drinking purposes must be pure, that is, free from the germs which cause such diseases as typhoid fever and cholera. Science has made it possible not only to obtain and distribute the necessary supply for all purposes, but also to prevent the germs from entering it and to purify the water which does contain these germs.

Following the unit on water supply, we shall consider one of man's greatest problems in life—that of KEEPING IN GOOD PHYSICAL CONDITION (Unit V). The human body is a very complex machine, which requires as essentials food, water, and air. Man's study of his own body has taught him how it works, the uses it makes of the three essential materials which are taken into it through the mouth and nose, the value and need of exercise, sleep, rest, and proper clothing, the care of its different parts, and first aid measures in emergencies. The science of keeping well is one of man's greatest fields of discovery. It is a science which you should know if you wish to be healthy, happy, and efficient.

As indicated in the last paragraph, proper methods of SELECTING AND CARING FOR OUR CLOTHING (Unit VI) have become a practical necessity for life. This is particularly true in certain regions where the climate and weather changes are marked. Cotton, linen, wool, and silk furnish us with many kinds of clothes. Rubber, straw, leather, and paper are also used. A knowledge of chemicals and their actions has made it possible to bleach, cleanse, and dye clothing materials as well as to make new materials. The body's need for protection and our artistic sense have led to the science of procuring and manufacturing clothing materials. Our knowledge of sanitation and our pride in cleanliness have resulted in our study of methods of keeping our clothes clean.

In connection with the care of the body and proper clothing we naturally think of the dangers of disease. No discovery of man is more important than that which Louis Pasteur, a French scientist, made during the latter part of the nineteenth century. It was he who first learned that the real cause of a certain disease was the presence of germs. As a result, we know today that most deseases are caused by germs, and it is possible to understand in part how the germs get into our bodies, how they make us sick, how we may avoid the spreading of disease, how we can protect the body against the ravages of the germs, and how our bodies should be treated when

we are sick. PROTECTING OURSELVES FROM DISEASE (Unit VII) has thus become a scientific matter of daily importance.

In his struggle with nature, man early learned how to make use of one of her greatest gifts, fire. Through a study of THE NATURE AND CONTROL OF FIRE (Unit VIII), man has found that fire can be used to cook his food, to furnish heat and light, and to make many of his building materials and tools. He has also learned what materials burn, and that the air and a certain temperature are necessary to cause burning. A great variety of uses of fire has been discovered. Many kinds of fire materials, or fuels, are used. Man's knowledge of fire has been one of his triumphs in understanding nature. He knows how to use it and also how to prevent its dangers.

Man seems never to be satisfied with his present conditions and knowledge. His desire for comfort, health, and efficiency, and his competition with others, have caused him to study and to discover many truths about nature, and to perfect many new inventions. PROVIDING HEAT AND FRESH AIR IN OUR BUILDINGS (Unit IX) represents two great steps in man's progress. Since the early days when man sat around the campfire or open fire to keep warm, great progress has been made in perfecting heating devices. We have our fireplaces, stoves, furnaces, fireless cookers, and other devices for using heat. What a change from the unpleasant open fire in one corner of the room and the smoky air within the hut to the modern steam or hot-water heating plant!

Through the use of fire and fuels, many MATERIALS FOR CONSTRUCTION (Unit X) have been made. In primitive times man lived in shelters made of trees or earth, and used for his tools such crude devices as he could make from wood or stone. When, however, he learned how to manufacture iron and steel and other metals, he could make tools, machines, and thousands of devices which we use today. Wood and stone could be cut to any shape; lime, cement, and glass could be manufactured; fireproof buildings could be constructed; modern heating devices could be made. Contrast our modern

homes and modern machinery with the shelters and crude tools of primitive man, and you will see what science has done for us in providing materials which we can use for making things.

Equally great progress has been made in man's use of tools and MACHINES FOR DOING WORK (Unit XI). The crude tools of former years, made of wood and stone, have been replaced by all sorts of metal tools and machines. Fire has made it possible to manufacture these, and today we find a variety of devices used to help man do what he formerly did with his unaided strength. Many of the simple tools and machines which use man's own strength as a source of "power" are found in every home and in every factory.

Man has also learned to save his strength and time by PUTTING THE FORCES OF AIR AND WATER TO WORK (Unit XII). He uses air pressure to operate pumps, siphons, and various simple devices. Air can be compressed and used to operate air brakes on trains as well as to inflate automobile tires. Windmills have been devised to make use of air in motion. Water has also been put to work in running water wheels of various kinds for the purposes of operating machines and of generating electricity.

As fire came to be better understood, it was used as a source of power. It is the heat of burning fuel which generates steam in the steam engine and which produces the power in a gas or gasoline engine. The forces of steam and exploding gas in these two kinds of engines saw our wood, cultivate the soil, dig ditches, harvest the crops, make roads, propel our automobiles, steamships, airplanes, and locomotives, run all kinds of complicated machines in factories, and, in many other ways, work for us. USING STEAM AND EXPLODING GAS FOR POWER (Unit XIII) will be an interesting problem for your study.

And now we come to GENERATING AND USING ELECTRICITY (Unit XIV), in which everyone is interested. Fire and electricity are the great sources of power used today. The first part of our study of electricity will consider how electricity is generated by cells. You have seen or used dry cells and storage

cells. But do you know how they furnish electricity and how they are made? Our second step in understanding electricity is to consider how electricity is made by dynamos and how it is used for running machinery, for electroplating, and for furnishing heat. At the same time you will learn how the electric motor works, for it is this machine which makes use of the electricity generated by dynamos, and so helps us to do our work.

Fire and electricity have been referred to as two of nature's greatest forces which man has used for heat, light, and power. Through the use of these forces for LIGHTING OUR BUILDINGS AND STREETS (Unit XV), our modern homes, factories, office buildings, and streets have become safer, more pleasant, and more comfortable. Artificial light is only another of man's great discoveries which has changed our ways of living. The use of gas and electric light, as well as a better understanding of how to use the sunlight, has contributed much to our civilization.

By the use of electricity and other forces we have made great progress in COMMUNICATING WITH OUR NEIGHBORS (Unit XVI). As man came to live in different sections of a country and in different countries, he needed ways to communicate with people at a distance. Think how modern communication compares with the crude methods of sending messages used until only a few score years ago. Today we talk by long distance telephone from one end of the country to the other and send wireless messages across the oceans. How do these instruments make use of electricity to send our messages? Certainly you will wish to find out in your study.

One of the very important purposes of air, steam, and electric power is that of TRANSPORTATION BY LAND, WATER, AND AIR (Unit XVII). Modern methods of transportation have made it possible to travel and to exchange all kinds of materials with people living in different states and different countries. From the previous part of this story you understand something of how nature's great forces have been

harnessed by man. You know that engines, motors, and other devices furnish "power" for running machinery and for transportation on land. In this last unit of the book you will see how man has learned to travel by land, water, and air.

If you would know more about the wonderful discoveries and inventions mentioned in this story, you must study them. You must read the text, do the experiments, and test your understanding by means of the exercises. The scientist who thoroughly studies any problem constantly keeps his problem in mind, and then by reading and experimenting tries to solve it. He does not "jump to conclusions," nor is he satisfied with half-knowing. He works carefully and accurately until he feels sure that his conclusion or answer is correct. It is in this spirit that you should study this book, following the suggestions given in Section (*B*.)

(*B*) HOW TO STUDY THIS BOOK

At the beginning of each unit of this course you will find several PRELIMINARY EXERCISES. These will help you to recall what you already know about the subject-matter of each unit. Write your answers in your notebook. If you cannot do all of them at the start, do those which you can. Most of these exercises were suggested by boys and girls in other science classes. It will be interesting to see how many *you* can do before studying the unit. At the end of the unit you can return to these exercises and complete all of them, changing any answers which were not correctly made before your study of the unit.

Following the doing of the exercises, the teacher will tell you the story of the unit, or you may be asked to read it as it is given on the first few pages. This story will make your study more interesting and more meaningful, for you will see where you are going and how each day's work relates to the unit. Ask the teacher to explain the points you do not understand when the STORY OF THE UNIT is finished. If you

have questions about points which were not mentioned, write them on a sheet of paper and hand them to the teacher or to the class secretary. These questions can then be answered later in class discussion. When you clearly understand the story, make a brief outline of the main points. Then write the story of the unit in your notebook as you would tell it to your parents, your younger brother or sister, or your friends. Each main point of your outline will make one paragraph of your story.

With a clear picture of the unit in mind, you can now begin to study the problems which follow. Each of these problems you can solve by careful study. When you take up a problem, read it through rapidly to see what it is about; then go back and study it carefully, doing the experiments and exercises. Look up all cross references given in the text. Also, use the table of CONTENTS for further help on any subject. Follow the suggestions given at the beginning of the index. The pronunciation of all difficult terms and names are given in a PRONUNCIATION LIST beginning on page 575. During your study of this book learn to pronounce the words correctly.

The exercises you will enjoy doing because they will give you an opportunity to show how well you understand the problem. If you cannot do them at the first attempt, go over the problem again, and, if other books are at hand, read what they say about this problem. (See REFERENCES AND GUIDE FOR ADDITIONAL STUDY, page 513.) When you are sure that you can do the exercise, do it. This method of study will let you test yourself. You will know when you really understand the problem or any part of it.

When you have finished all of the problems and the exercises and feel that you fully understand the unit, you may be asked to make an outline of all you have learned. This outline may be topical or in statement form, as the teacher requests. Write the title at the top of your notebook paper, and then write the main points below, dividing each main point into the important ideas which you have gained in your

study. Instead of the outline, your teacher may ask you to write the complete story.

When all students have finished the outline or story, the class will spend a day or two discussing the unit. You may be asked to talk on the entire unit, on one of the main points in your outline, or on one of a list of recitation topics given by the teacher. In any case, you should be able to speak on your topic before the class for several minutes, using the blackboard to illustrate what you say or sometimes performing experiments before the class, in order to make your speech interesting and clear. If you know your subject thoroughly, you will enjoy talking about it to the class. Moreover, your classmates will enjoy your talk if you give it with clearness and in an interesting, forceful way.

If you finish your work on any unit ahead of your class, or if you have extra time outside of class, you may have the privilege of doing additional work. Consult with your teacher about your plans, and bear in mind that there are three kinds of additional or supplementary study which you may choose to do. First, you may do the ADDITIONAL EXERCISES AND PROJECTS listed at the end of each unit. Second, you may read one or more of the interesting REFERENCES listed in the section beginning on page 513. Third, you may select one of the TOPICS AND PROJECTS FOR INVESTIGATION following the REFERENCES on each unit.

The ADDITIONAL EXERCISES AND PROJECTS are for the careful, rapid worker. They are good tests to see if you can use the knowledge gained in the study of the unit to solve new problems. Most of them require but little time and may be done in the classroom when you have a few spare minutes.

For your guidance in further reading turn to the REFERENCES AND GUIDE FOR ADDITIONAL STUDY beginning on page 513. There you will find a list of books and pamphlets for each unit. Following the list and under the title "Guide to References" are two kinds of reading material. Those marked "General" present subject-matter similar to that considered in your study

of the particular unit. Then appear other references dealing with "Specific Topics" or problems met in the unit. Through reading these general and special references you will better understand the unit.

The TOPICS AND PROJECTS FOR INVESTIGATION are for those students who wish to undertake work outside the class. Each topic or project will require careful study. Consult with your teacher before selecting one. When you have completed the work on one of these, you should be ready to give an oral or written report to the class or to the teacher.

Real success in your work during the course in science means that you will do three things: (1) complete the required work on each unit promptly and thoroughly; (2) do considerable outside reading in the reference books, magazines, and pamphlets; (3) do the additional exercises at the end of each unit and also several topics and projects for investigation. Then you will feel the satisfaction of having proved that you have the qualities of a good citizen.

EVERYDAY PROBLEMS IN SCIENCE

UNIT I

THE EARTH ON WHICH YOU LIVE

How to begin your study of this unit. Do the Preliminary Exercises below. These will help you in the later study of the unit. Write out as many of the exercises in your notebook as you can, making a title for each. For example, call Exercise 1 "Heavenly Bodies I Know." Follow the plan given on page xxxi in the preceding section, "To the Student," which you should read before beginning work on this unit.

Preliminary Exercises

1. Name as many different kinds of heavenly bodies as you can.

2. Make a list of the eight planets. If you can, arrange them in the order of their size, from largest to smallest.

3. What are two movements of the earth? How do these movements influence your life?

4. Write a paragraph on the subject, "Why I Believe the Earth Is Round."

5. How does the time of sunrise and sunset change throughout the year?

6. The solid surface of the earth was once nothing but rock. How do you account for the presence of the different kinds of soil which exist today?

7. Why is it hotter in summer than in winter?

8. People set their watches ahead or back at certain places when they travel east or west. Why do they do so?

9. Man's study of the heavenly bodies has resulted in knowledge which serves him in many practical ways. List as many facts as you can to show that this is true.

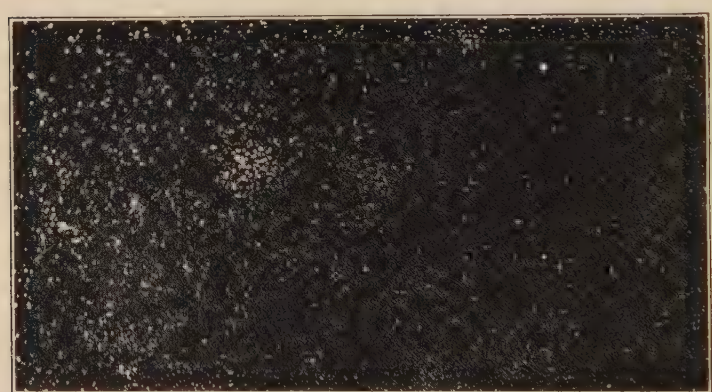
10. Name the constellations which you know.

11. What is meant by latitude? By longitude?

12. Turn to the Preliminary Exercises of Unit II (page 35) and begin Exercises 3 and 5 now, keeping your records complete for every day until you reach Unit II in your study.

THE STORY OF UNIT I

The earth on which you live is a small body among millions of other heavenly bodies. Let us try to get a mind picture of the great universe of which the earth is such a small part.



Courtesy Yerkes Observatory

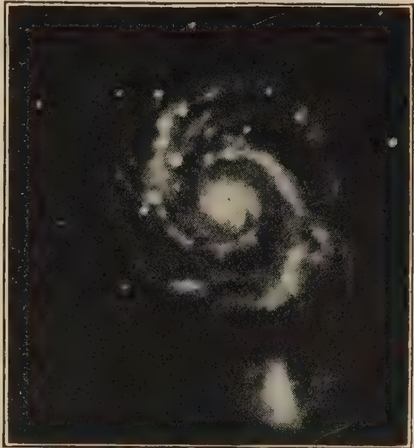
Fig. 1. A Starry Night

Seen through a telescope, a small part of the sky shows countless stars, some of which appear to be arranged in clusters.

As you look at the heavens on a clear, moonless night, there seems to be no end to space nor to the number of heavenly bodies (Figure 1). You can see over 2000 *stars*. Millions of others are too far away to be seen with the naked eye, or are hidden from your view by the earth. Among the stars may be seen with a telescope many patches of light, some of which appear like wheels with blurred spokes. The central part

appears like the hub of the wheel. These bodies, called *nebulas*, are composed of solids and gases (Figure 2).

While the stars and nebulas look like mere specks or small patches of light, they are really enormous bodies. Many of them are larger than our sun, which is 866,000 miles in diameter. They appear small because they are many millions of miles away. You know that large things seem very small when they are at a great distance. You can, therefore, imagine how large the stars are, what great distances separate them, and how enormous the *universe* is.



Courtesy Yerkes Observatory

Fig. 2. A Spiral Nebula

Millions of miles in diameter and whirling at a terrific speed this great nebula may some day form a new sun and earth like our own.

To get a somewhat better picture of the size of the world let us look at a star in daylight. On a clear day you see one of the nearest stars, the *sun*. It is only a medium-sized star but looks very large. If you could go far out in space to one of the distant stars and see the sun, it would be a mere speck of light. But because it is only 93,000,000 miles from the earth it appears much larger than other stars. It seems strange to say "only 93,000,000 miles" away, but when you consider that the next nearest star is hundreds of thousands of times as far from us as the sun, you see that the distance to the sun is comparatively small.

While the stars are millions of miles from the sun, there are several large bodies, not stars, near the sun. The most important of these are the *planets*, or wanderers, so-called because they seem to move so rapidly. Imagine that you are far out

in space looking at the sun and the planets (Figure 3). The sun appears very bright because, like all visible stars, it is extremely hot and therefore gives off much light. Eight planets can be seen. These do not give light of their own, but

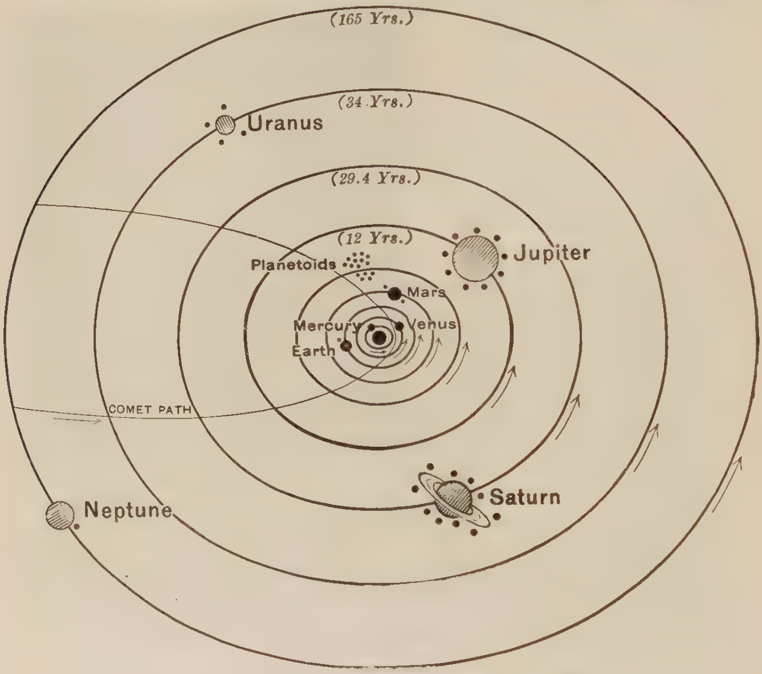


Fig. 3. The Sun and Its Family

The planets revolve around the sun and are members of its family. In this figure the sun is shown as a black circle at the center. The sizes of the bodies and of the paths are, of course, not in proper proportion in this figure.

are visible because the sunlight which strikes them is *reflected* back to you. The planets appear small, but they are really from about 3000 to 86,000 miles in diameter. All are *revolving* around the sun in the same direction. They travel at different speeds and are at different distances from the sun. Each

planet has its own path, or *orbit.* The third from the sun and the fifth largest in size is the earth. This little body—it would appear small from your position in space—spins on its axis once during every day. This motion is called *rotation.* It also travels around the sun, making one *revolution* in about 365¼ days.

Fig. 4. Relative Sizes of the Sun and Planets

The sun is over 100 times as great in diameter as the earth. See Table I, page 20, for diameters in miles of these bodies.

Before you return from your imaginary trip, look more carefully with a telescope at the sun and its neighbors. You see a body about one-third as large in diameter as the earth revolving around the earth. Also you can see similar smaller bodies, called *moons* or *satellites,* moving around some of the other planets. And with your telescope you can see several hundred *planetoids,* or little planets, revolving around the sun. These are between the four planets nearest the sun and the four farthest away. Their paths around the sun are nearly circular, like those of the planets. The entire group including the sun, the planets, the moons, and the planetoids makes up the sun family, or *solar system* (Figure 3; examine also Figure 4).

From the earth—you have now returned from your trip in space—you may sometimes see two other kinds of bodies. The *meteors,* or "shooting stars," often to be seen at night,

are not real stars, but small bodies which fall from space into the air covering of the earth. As they pass through the air they become very hot because of the resistance of the air. Sometimes they "burn up" and fall to the earth as dust. These meteors can be seen from the earth because they give off light when hot. Often they fall to the earth and are found to vary greatly in size. Some are no larger than marbles; others weigh several tons.

Courtesy Yerkes Observatory

Fig. 5. A Flaming Comet

An actual photograph taken with a camera through a telescope. The stars appear as streaks because the camera had to be kept moving.

The *comets*, seen less frequently, are very large bodies with heads from thousands to millions of miles in diameter, and often with flaming tails millions of miles in length (Figure 5). These visitors to our solar system can be seen for short periods and then disappear for a long time. They travel around the sun in paths which are not circular but of the shape shown in Figure 3, and are visible only when they are near the earth.

Of all the bodies in the universe the earth is naturally the most important and most interesting to you, for it is your home. This great ball, nearly 8000 miles in diameter and 25,000 miles in circumference, has two movements which greatly influence your life. Your daily work and sleep, your work and play at different seasons of the year, and even the time of day, depend upon the rotation and revolution of the earth, for day and night, weather and climate, seasons, and

time are all determined by these movements. During every rotation you go to bed once and rise once; for every revolution you are one year older.

Not only are the movements of the earth of great importance to you, but what the earth is made of, that is, its *composition*, also governs what you do and provides everything which you have. The earth consists of a solid interior, a surface composed of *land* and *water*, and a layer of *air* above the surface (Figure 6). The solid part of the surface is made of land forms, such as continents, islands, mountains, plateaus, valleys, and plains. Water in the form of rivers, lakes, and oceans covers a large part of the surface. Above the land and water is a layer of air with a depth estimated to be from 50 to 200 miles. These *materials* make life possible on the earth. You breathe the air; drink the water; obtain light and power from the electricity generated by waterfalls; eat the food which grows in the soil, water, and air; live in houses made from rocks, metals, bricks, and wood; and in a thousand and one ways you depend upon the forces and materials of the earth.

Fig. 6. A Slice Through the Earth

This picture greatly exaggerates the depth of the air and the unevenness of the surface of the earth. In proportion to its size the earth is as smooth as the peel of an orange.

As you study the following problems of this unit and of later units, you will find an interesting story of some things which man has learned about the materials which nature has provided. You will come to see that you are a mere speck in

the great universe, and that if you have the mind and will to understand nature better, you can live a happier, more wholesome, and more worthwhile life.

Fig. 7. Constellations of the Northern Hemisphere

Many interesting stories are told about these and other figures which men imagined they could see in the heavens.

PROBLEM 1: HOW CAN YOU LOCATE THE STARS?

In earlier times men grouped the stars into *constellations* or outline pictures of men, beasts, and weapons (Figure 7). For each constellation they told an interesting story, or

myth. While we do not today believe the stories which they told, we do retain their names for the constellations and for most of the stars. These constellations are easily located,

Fig. 8. A Star Map

The constellations which may be seen during the fall of the year in the Northern Hemisphere are outlined and named in this figure. The numbers in parentheses indicate some of the brightest stars as follows: (1) North Star, or Polaris, (2) Capella, (3) Vega, (4) Arcturus, (5) Antares, (6) Altair, (7) Fomalhaut.

and through knowing them you can find the principal stars. Figure 8 shows the constellations which can be seen in our part of the Northern Hemisphere during certain months.

In order to know the stars you must have some way of locating them. Figure 9 shows a few of the constellations near the *Big Dipper*, the part of *Ursa Major* that looks like a dipper.

Fig. 9. Chart of Principal Northern Constellations

To locate any of the seven constellations, hold this map or chart directly north of the eye, having Polaris of the map in line with Polaris of the sky. Turn the map until the name of the present month of the year is at the bottom, and at 8:00 p.m. the constellations will appear in the sky in practically the same positions as on the map.

You must keep in mind that the constellations appear to turn around the *North Star*, or *Polaris*, or rather around a center near the North Star, if you wish to find them at any time

of the year. Those in the northern sky near Polaris are always visible in the Northern Hemisphere.

To find the North Star, start at the Big Dipper. The two stars (*A*) and (*B*) in Figure 9, on the side of the bowl opposite the handle, are called the pointers. Imagine a line drawn through these two stars, starting at the bottom of the bowl and extending beyond the Dipper five times the distance between the pointers, and you come to the North Star, which is about as bright as the pointers.

The North Star is the end star of the handle of the *Little Dipper*, a group of seven stars in Ursa Minor. If you imagine yourself coming out the line which you followed from the Big Dipper to the North Star, and then, when you reach the North Star, turning to the left, you can easily find the Little Dipper.

A third constellation near by is *Cassiopeia* (kăs′ĭ-ŏ-pē′yȧ), the queen on her chair. To find her, draw a line from the middle of the handle of the Big Dipper to the North Star and extend it as far beyond as the distance from the Big Dipper to the North Star. Here you find a "W" shaped group of five bright stars which form the chair on which the queen is seated.

Going two-thirds of the way from the North Star toward Cassiopeia and making a left turn, you find *Cepheus* (sē′fŭs), the queen's husband. From the maps showing the constellations you can work out the location of any of the other constellations, such as *Perseus* (the son of Jupiter), *Auriga* (ô-rī′gȧ) (the charioteer), *Bootes* (the bear driver), *Hercules* (the warrior), and *Draco* (the dragon). After you find the principal constellations, you can locate the bright stars, numbered in Figure 8, by the names below the figure.

Fig. 10. Big Dipper in August Position

Exercise 1. Suppose you looked at the northern sky and found the Big Dipper in the position shown in Figure 10. Copy the figure and show the position of the constellations, using the directions given in the preceding four paragraphs.

PROBLEM 2: WHAT IS THE NATURE OF THE PRINCIPAL BODIES IN THE SOLAR SYSTEM?

The sun is the center of the solar system. Although it is a small star, the sun is so near us that it furnishes the heat and light which make life possible. It also keeps the earth and other planets in their paths by its attraction for them. This attraction is called *gravity*. The size of the sun is enormous when compared with the earth; its diameter is about 110 times as great, it weighs over 300,000 times as much, and it occupies over 1,000,000 times as much space. This great ball of fire rotates on its axis just as the earth does.

The planets are not all alike. The eight planets are similar in many respects, but like members of any family they differ in a number of ways. Since you already know that they travel around the sun, let us see how they differ from each other. We will consider them in the order of their distance from the sun.

Mercury, called the messenger because of its great speed, is the nearest planet to the sun and the smallest in size. Because it is so small, the force of gravity is not great enough to hold air around the planet. It is often quite close to the earth, but is usually invisible because it is so near the sun and therefore lost in its rays. When visible to the naked eye, Mercury is seen as a red body, but appears to have a dull silver color when observed through a telescope.

Venus, the lovely planet which you so often see as the evening or morning "star," is nearer the earth than any of the other planets when it is on the same side of the sun as the earth. It shines in the west as the evening star for a period of seven or eight months, then disappears for a few weeks, and appears again in the east as the morning star. When viewed through a telescope, Venus shows, at different times, the various shapes of our moon. Like the earth it travels around the sun in a nearly circular orbit. In fact, it is so much like the earth that the two are often spoken of as the twin planets.

Because we shall study the earth in later problems, let us next consider *Mars*, the red planet, so named for the

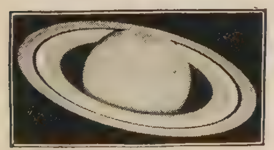
god of war. Rotating on its axis like a spinning top once in 24 hours and 37 minutes, its day and night are almost of the same length as ours. Like the earth, Mars has four seasons. It is doubtful whether there is any air around it, but a white spot which can be seen through a telescope near its north pole during the winter season, and which looks like snow, suggests that there may be some water vapor around the planet (Figure 11). This spot is not visible when it is summer on Mars.

Courtesy Yerkes Observatory

Fig. 11. "Snow Caps" on Mars

These white spots appear and sometimes disappear at different seasons on Mars.

As we move farther from the sun and leave Mars and the other small, or minor, planets behind, we come to the major planets, of which the nearest to the sun is *Jupiter*, the giant. Like the other major planets, its surface is probably composed of gases. A thousand times as large in volume as the earth, and larger than all of the other planets put together, Jupiter rotates on its axis in 9 hours and 55 minutes, at the enormous speed of 30,000 miles per hour, and, being far from the sun, revolves around the sun in approximately twelve of our years. Nine moons revolve around Jupiter, two of them larger than the planet Mercury. Four of these moons were the first heavenly bodies to be discovered with the telescope. Galileo, an Italian using the first telescope, found them in 1610.



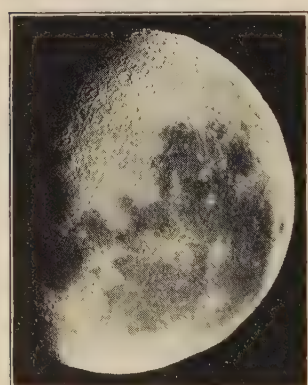
Courtesy Yerkes Observatory

Fig. 12. The Beautiful Planet

Saturn, the next planet from the sun, is, on account of its rings, one of the most beautiful planets when observed through the telescope (Figure 12). These rings are nothing more than a great number of very small satellites, revolving around the planet. It rotates rapidly on its axis and revolves

around the sun in $29\frac{1}{2}$ years. It has four seasons like the earth, but they are each over seven years long. Ten moons, one larger than our moon, revolve around Saturn.

When Herschel, an English astronomer, made his own telescope in 1781, he discovered a moving "star" which was at first thought to be a comet, but proved to be a planet. This planet, which is farther from the sun than Saturn, is called *Uranus*, although in England it is sometimes called Herschel, after its discoverer. It has a volume sixty-five times as great as that of the earth. Four moons revolve around the planet.



Courtesy Yerkes Observatory

Fig. 13. Our Nearest Neighbor

Seen through a telescope, the surface of the moon appears like this. Life cannot exist on such barren rock.

The last of the planets is *Neptune*, four and one-half times as great in diameter as our earth, and thirty times as far from the sun. It cannot be seen with the naked eye. The most interesting thing about Neptune is the way in which it was discovered. Astronomers had noticed that Uranus did not travel in exactly the path which they had expected from a study of the planet's movement. This led them to study why it did not follow the path, and they predicted that it was pulled out of the path by another planet, not yet discovered. By further study they predicted where the planet would be found, located it with the telescope, and named it Neptune.

Exercise 2. Name the planets on which you think life does not exist. Following each, give your reasons.

The moon is our nearest neighbor. Although several of the planets have one or more moons, the moon of the most interest and importance to us is that of the earth (Figure 13). This satellite is very different from the earth. Because it is only

240,000 miles away, it looks as large as the sun, but it is really only 2160 miles in diameter and weighs only one-eightieth as much as the earth. You could not live on the moon, for there are on it no air, no water, no soil, no plants, and no animals. The surface is solid rock. When viewed through a telescope, it appears very rough with high mountain-like projections and with large holes like the craters of volcanoes.

The moon has two important movements. It travels around the sun in its orbit, and as it does so it moves back and forth across the orbit of the earth, as shown in the upper part of Figure 14. This back and forth movement and its change in speed at different parts of its orbit cause it to revolve around the earth. If viewed from far out in space, the earth and moon would be seen moving along as shown in the upper part of Figure 14. But when they are observed from the earth, the moon appears to move as shown in the lower part of the picture.

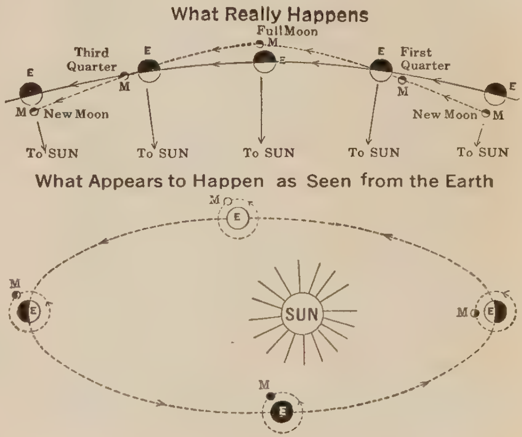


Fig. 14. Travelers in Space

As the earth revolves around the sun the moon is carried along while it revolves around the earth.

Experiment 1: How does the moon move around the earth?

Draw a large circle several feet in diameter. Imagine that the sun is at the center of the circle and that the earth revolves around it along the circumference of the circle. Place a large ball or orange on the circumference to represent the earth. Now obtain a small

ball or a marble to represent the moon. Have the earth and moon in the positions shown at the right of the upper part of Figure 14. Now move the earth along the circumference of the circle (its orbit), and at the same time move the moon along its orbit as shown in the figure. Note that the moon is actually revolving around the earth as you proceed to the different positions of the earth and moon as represented in Figure 14.

From your experiment and your study of Figure 14 you can imagine the earth and moon in space, moving around the sun. You see the earth making one revolution in $365\frac{1}{4}$ days, and the moon going along like a real satellite. However, the moon travels in its own orbit and thus makes a complete turn around the earth once every $29\frac{1}{2}$ days, or a little less than a month. From the earth you see the moon rise and set as the earth rotates. If you note the time when the moon rises on two successive nights, you will find that it rises about 50 minutes later each night. This, you can see from your experiment, is true, because the moon revolves around the earth.

The moon appears to change shape. An interesting thing about the moon is its apparent change in shape. On different nights it sometimes appears round, sometimes like a very thin crescent, and at other times like a quarter-circle. This change is only apparent; that is, the shape merely seems to change. The moon, like the planets, does not give light of its own, but reflects the light of the sun. The half of the moon that faces the sun is always lighted, but is not always visible from the earth. If all of the surface of the moon which faces the earth could always be seen, the moon would appear round or full at all times. An experiment in a dark room will show how it appears in different shapes, or *phases*.

Experiment 2: Why does the moon appear to change its shape?

Obtain a candle and a tennis ball, which are to be used to represent the sun and moon, respectively. You are to represent the earth. Place the lighted candle on a table or stand. With your back to the candle hold the ball (the moon) in your outstretched hand, high enough above your head to allow the light

to strike the ball. What part of the ball is lighted by the candle (the sun)? Now turn around slowly from right to left, keeping the ball in front of you and slightly above your head so the light will strike it. Observe what part of the ball is lighted as you turn. Repeat your turn, stopping at every one-eighth turn and drawing the shape of the part of the ball that is lighted. Do you get the same shapes as those shown in the inner circle of Figure 15? If not, try it again.

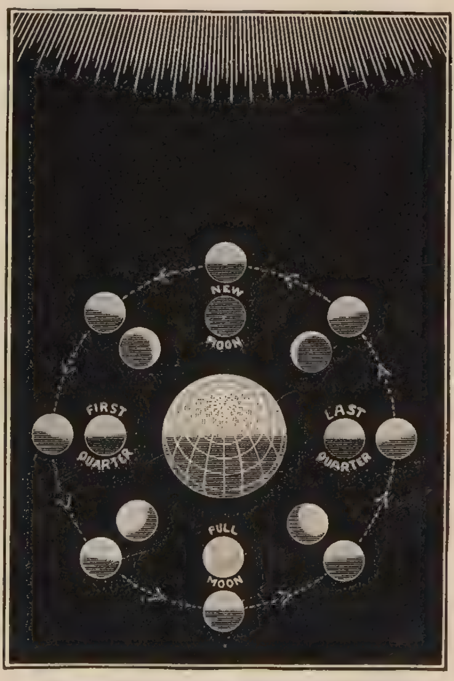


Fig. 15. Phases of the Moon

On the outer circle you see that the half of the moon which is toward the sun is always lighted, while on the inner circle is shown the shape of the lighted part as it appears to one on the earth at different times of the month.

If you now examine Figure 15 again, you will see why the moon changes its appearance regularly. It requires about $29\frac{1}{2}$ days for the moon to make its trip around the earth and get back to the same position with respect to the earth and the sun.

Exercise 3. Many people think that the moon changes its shape. Write a short composition which such people could read to learn what really happens.

Exercise 4. Explain why the moon would appear to anyone on earth as it does in Figure 13.

Exercise 5. Show by calculation how many times the moon revolves around the earth while the earth revolves around the sun.

At certain times it happens that the earth gets directly between the sun and moon. The shadow of the earth then hides the moon from our view, and we have an *eclipse* of the moon, or a *lunar eclipse* (Figure 16). Or the moon may come between the earth and the sun. If the shadow of the moon strikes the earth, it hides all or a part of the sun, producing a *solar eclipse* (Figures 17 and 18).

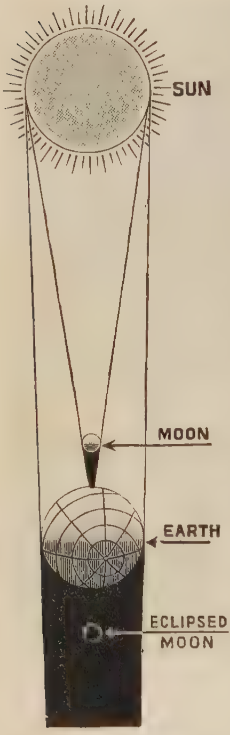
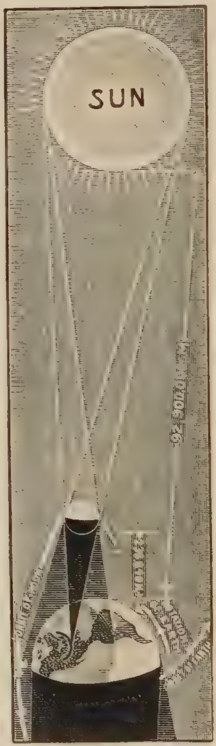


Fig. 16. How the Moon Is Eclipsed

The dark section below the earth is the earth's shadow. Whenever the moon passes into this shadow, it is eclipsed from our view.



Pacific and Atlantic Photos

Fig. 17. How the Sun Is Eclipsed

In January, 1925, the moon caused a total eclipse of the sun along a path in the northeastern part of the United States.

The moon is one of the causes of the tides. If you have ever been at the seashore, you have observed the regular rising and falling of the water at different hours of the day. These *tides*, which are so important to people who live and work on the ocean front, are due in part to the moon. Twice in about 25 hours the tides rise and fall, producing two high tides and two low tides in this period of a little more than a day. The moon helps to cause these tides by its attraction for the earth. As the earth rotates, the

part of its surface nearest the moon is attracted more than the other sides of the earth. This is true because the nearer bodies are to each other, the greater is the force of gravity. This attraction causes the water in the seas and in the mouths of rivers that run into the sea to be pulled up a few feet higher at this part of the surface, causing a high tide (Figure 18). On the opposite side of the earth, which is farthest away from the moon, the moon's attraction is not so great, but the water is piled up

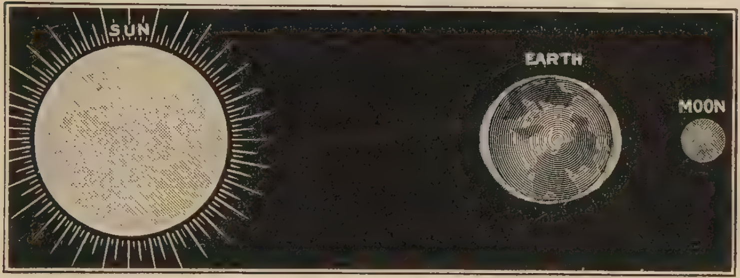


Fig. 18. How Tides Are Caused

The water, being a liquid, is free to move and, having weight, is attracted by the sun and moon. This causes it to rise at certain places and thus become lower at other places. Meanwhile the earth rotates, and the places of low tide and high tide change constantly.

there by the outward, or *centrifugal,* force of the rapid spinning of the earth and by the attraction of the sun. These two forces produce a high tide at that place. Between these two parts of the surface the attraction of the moon and sun is more nearly balanced by the centrifugal force of the rotating earth. The water at these places is, therefore, low (Figure 18). You can see, then, why there are two low tides and two high tides daily on any seashore. You might expect a high tide to occur every 12 hours because the earth rotates once in 24 hours. You will recall, however, that the moon is 50 minutes later each day. Thus the high tide occurs every 12 hours and 25 minutes.

Exercise 6. State three forces which cause tides.

The principal bodies in the solar system. The table below shows some interesting facts about the solar system.

TABLE I: INFORMATION ABOUT THE SOLAR SYSTEM

BODIES	DISTANCE FROM SUN (in millions of miles)	DIAMETER IN MILES	REVOLUTION AROUND SUN	ROTATION ON AXIS	WEIGHT (compared to equal volume of water)
Sun.....		866,540		25 days	1.50
Mercury..	36	2,765	88 days	unknown	6.85
Venus...	67	7,700	225 days	unknown	4.85
Earth...	93	7,918	365¼ days	24 hours	5.58
Mars...	142	4,230	687 days	24 hrs. 37 min.	4.01
Jupiter..	483	86,500	11⅞ yrs.	9 hrs. 55 min.	1.38
Saturn...	886	73,000	29½ yrs.	10 hrs. 14 min.	.72
Uranus..	1,782	31,900	84 yrs.	unknown	1.22
Neptune..	2,790	34,800	164½ yrs.	unknown	1.11
Planetoids	200 to 300	20 to 300	3 to 7 yrs.	unknown	unknown
The moon satellite	93	2,160	365¼ days	27.6 days	3.50

Exercise 7. Using the diameters of the planets given in Table I, draw circles to represent the comparative sizes of the planets. Start with a circle $\frac{1}{8}$ inch in diameter to represent Mercury and draw the other circles on the same page. Label the circles at the side with the names of the planets.

Exercise 8. From a study of Table I answer the following questions:

(*a*) What is the order of size of the eight planets?

(*b*) What are the names of the planets in the order of their distance from the sun?

(*c*) Which is the heaviest planet for its size?

(*d*) If you traveled 100 miles per hour for 24 hours each day in an airplane and could fly from the earth to the sun, how many years would it take you to reach the sun?

(*e*) How many bodies as big as the earth would have to be placed side by side to make a string as long as the diameter of the sun?

(*f*) How much longer does it take Jupiter to revolve around the sun than it takes the earth?

(*g*) How many times does the earth turn on its axis while the moon rotates once?

(*h*) How far is it around the sun if the circumference of a circle is 3.14 times the diameter of a circle?

PROBLEM 3: HOW DID THE EARTH COME TO BE AS IT IS TODAY?

The origin of the earth is unknown. Although scientists have tried to find an explanation of the origin of the earth, no one can say with certainty how the earth was formed. Many astronomers believe that the solar system came from a great rotating nebula like that shown in Figure 2. This body, they believe, was formed when two stars collided or came very near each other and became a great rotating mass of materials. The nebula was millions of miles in diameter, with a large central part of thick or dense material and with large curved arms of thinner material. Here and there in the nebula were spots or masses of thicker material. Many such nebulas, like that shown in Figure 2, may be seen in the heavens today.

As this nebula rotated, the thinner materials in it separated and collected around the thicker or denser spots. The center became the sun and the spots in the arms became the planets, moons, and planetoids. All of these bodies continued to rotate. The planets continued to revolve around the sun, or center, and the moons revolved around the planets.

The earth is very old. No one knows how old the earth is. Scientists have, however, estimated its age by calculating how long a time would be required for streams to carry enough salt into the seas to make them as salty as they are now, by studying the rock formations, and by determining how long it takes to crumble rocks into *soil* and to cut gorges like that of the Niagara River. These estimates vary from 100,000,000 to 400,000,000 years.

The earth is ever changing. As the interior of the earth cooled, the solid crust was pushed up in some places. This action formed mountains and plateaus and left low places at

other parts of the earth's surface. The surface of the earth became very irregular. Some of these low places filled with water, forming the oceans.

Courtesy School of Education, University of Chicago

Fig. 19. From Rock to Soil

Roots of trees, falling rock, burrowing animals, waves, and changes of temperature are some of the forces acting on rock to crumble it into soil. But for these forces fertile fields would be impossible.

During the millions of years since this happened, the rock surface of the earth has been broken up and moved in many ways (Figure 19). The air caused some of the rocks to crumble. Water, freezing in the cracks of the rocks, split them into smaller pieces. Running water has cut into the rocks and ground the broken pieces into fine particles which were carried along by the water and dropped in other places as different kinds of soil. The action of waves along the shores of lakes and oceans has worn away rocks and carried the pieces to other places. Also great ice sheets, or *glaciers*, broke and ground the rocks, and carried them to other regions, and wind moved the finer particles from one place to another. All of these changes in the earth's crust are still going on.

One of the most remarkable changes on the earth was the coming of living things. In some way, and many centuries ago, life began in the soil and water. Today there are millions upon millions of plants and animals. These vary in size from the most minute living things, so small that they may be seen only with the aid of the most powerful microscopes, to such huge plants as the giant trees of the forest or such enormous animals as the elephant and the whale. All of these, including yourself, live together and are dependent upon each other as well as upon the many materials and forces of nature. The materials obtained from the rock, soil, water, and air furnish you and all living things with everything needed except the light and heat from the sun. These materials and the many forces of nature, such as growth, disease, weather and climate changes, heat, light, electricity, wind, and others, determine how and where living things grow. They are a part of your surroundings, or *environment.*

You see from this that your environment is very complex and interesting. It will be even more interesting as you learn more about science.

Exercise 9. Turn back to the beginning of Problem 3 and read each paragraph carefully so that you can write in one short sentence the main idea in the paragraph. Set this down in outline form with the principal points in each paragraph under the main idea, as shown in the following outline. Copy the outline below and complete it for all paragraphs of Problem 3.

How the Earth Came to Be As It Is Today

1. The solar system was probably formed from a nebula.
   (*a*) The nebula probably came from a collision of stars.
   (*b*) It was a hot gaseous mass of material.
   (*c*) The center was dense and became the sun.
   (*d*) The denser spots, outside the center, formed the planets and moons.
   (*e*) The planets and moons continued to rotate and revolve around the sun.
2. Scientists have estimated the age of the earth.

PROBLEM 4: WHY DO THE DAYS AND NIGHTS DIFFER IN LENGTH?

But a few centuries ago man believed that the sun revolved around the earth, and that the earth was flat and surrounded by water. Later, man learned that the earth is round, that it spins on its axis, and that it revolves around the sun.

Exercise 10. Give one reason for believing each statement in the last sentence to be true.

The days and nights vary in length. The earth receives its light from the sun. Being round, only one-half of the earth's surface can be lighted at one time. Since the earth rotates on its axis at a regular speed, once every 24 hours, you might expect the sun to rise and set at the same time every day. If this happened the days and nights would be of equal length. Why? You know that the days and nights are not of equal length at different times of the year.

Exercise 11. Look up in an almanac the exact times of sunrise and sunset for the first day of each month and determine the exact length of day and night. Place your results in a table as indicated. As a conclusion state what you have learned about the length of day and night at different seasons of the year.

LENGTH OF DAYS AND NIGHTS

	SUNRISE A. M.	SUNSET P. M.	LENGTH OF DAY IN HRS. AND MIN.	LENGTH OF NIGHT IN HRS. AND MIN.
January 1...				

The angle of the sun's rays varies. You recall from geography that the unequal days and nights are caused by the *inclination of the earth's axis.* That is, the earth rotates in a plane inclined or tilted $23\frac{1}{2}°$ to the plane in which it revolves around the sun. A simple experiment will make this clear.

Experiment 3: What causes the days and nights to be of unequal length?

Push a straight wire or knitting needle about 6 to 8 inches long through the center of a tennis ball or a hollow rubber ball. The points where the needle leaves the ball should be marked *N* and *S* to represent the North and South poles. The candle is the sun and the ball is the earth. Now place an *X* on the earth to indicate the latitude at which you live. Draw a circle through *X* so that all points of the circle are at an equal distance from the North Pole.

Place a short lighted candle at the center of a circle one foot in diameter, drawn on a large piece of paper. The room should be dark. Place the earth directly south of the sun and have the North Pole end of the axis (the needle) point to the North Star. Note that the axis and plane of rotation of the earth are now tilted to the plane of revolution, or the table top (Figure 20).

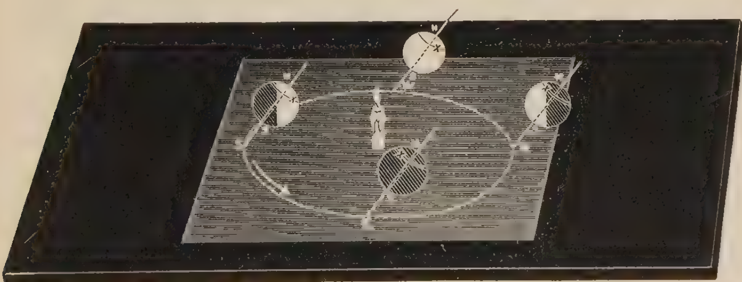


Fig. 20. Days and Nights Vary in Length

Observe that one-half of the earth is lighted, but that over one-half of the circle through *X* is lighted. If the earth is rotated, it will be seen that *X* remains in the light for more than one-half of one rotation. The day is longer than the night at *X*. Move the earth around the circle to a position east of the sun, but keep the axis pointed to the North Star. Rotate the ball and note that *X* is in the light for exactly one-half of a rotation. The day is now equal to the night. Let the earth be revolved on the circle until it is north of the sun. The day at *X* is now shorter than the night. When the earth is moved still further around and is west of the sun, the day and night at *X* are equal.

Exercise 12. Having in mind what you saw in the experiment, imagine the earth and the sun in space, and state the reasons why we have unequal days and nights at different times of the year in the Northern Hemisphere.

PROBLEM 5: WHY DO THE SEASONS CHANGE?

The changes in the seasons are as important to you as the varying lengths of days and nights. Throughout the greater part of the United States these seasonal changes affect life in various ways. Particularly in the country the seasons determine the kind of work that must be done. In both country and city the seasons govern largely the kind of clothes you wear, the games you play, the weather you have, and even the kind of food you eat. You know that it is warmer in summer than in winter, and that spring and autumn are more or less similar in temperature. As a scientist you should be able to explain why these changes occur.

The angle of the sun's rays changes every day. From your previous study you recall that the seasons are caused by the rotation and revolution of the earth. In the United States the sun rises a little south of east in winter and a little north of east in summer. You have probably observed that the sun is more nearly overhead at noon on a summer day in the Northern Hemisphere than it is at noon on a winter day (Figure 21). A simple experiment will show that the angle at which the sun's rays strike the earth varies from day to day.

Experiment 4: How does the angle of the sun's rays change from day to day at the same hour?

Cut a small round hole, about one-half an inch in diameter, in a piece of cardboard. Place the cardboard in a south window of a room so that the sun's rays will pass through the hole and strike a piece of paper on the floor, window sill, or table. Draw the outline of the spot where the beam of light which passes through the hole strikes the paper. Write the date and the hour inside the outline. At intervals of ten minutes repeat. On succeeding days, at exactly

the same time of day, draw the outlines of the spots, and note that the paths of the spots are farther from, or nearer to, the window.

The changing position of the spots from day to day shows that the sun's rays strike the earth at different angles on different days.

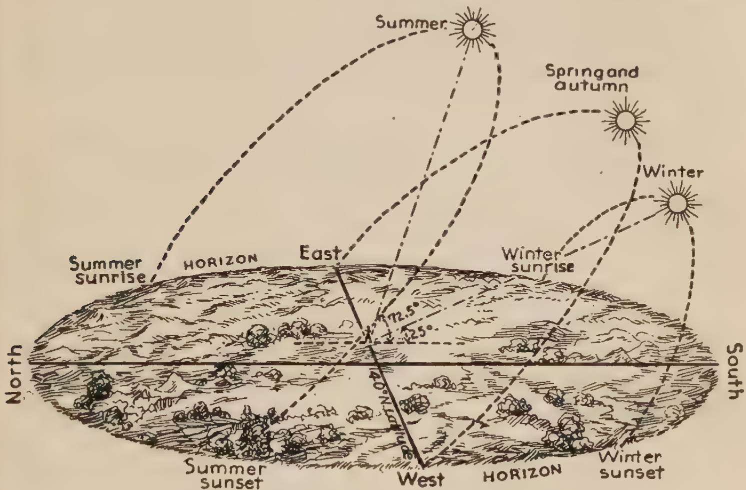


Fig. 21. Where the Sun Appears to Be

If the axis of the earth were not inclined to its orbit, the sun would appear to rise in the same direction throughout the year; there would be no change of seasons.

Exercise 13. If you carried out Experiment 4 on every day of the year, how would the distance of the spot from the window change? What does this show regarding the change in the angle of the sun's rays (*a*) from January to March, (*b*) from April to June, (*c*) from July to September, (*d*) from October to December?

The angle of the sun's rays affects temperature. Does the angle of the sun's rays determine the amount of heat which the earth receives from the sun? If it does you can see one reason why seasons occur, for you have found from the preceding experiment that the angle of the rays varies at different seasons. That the sun does warm the earth you know from experience. The rays come through the space

between the sun and the atmosphere, and then through the air before they strike the earth. They do not heat the space above the air, for there is no material present. However, when the rays strike the air and the surface of the earth, they change to heat which affects the temperature.

You can learn from an experiment one reason why the angle of the sun's rays has an effect on the temperature of the earth's surface.

Experiment 5: How does the angle of the sun's rays determine the amount of light and heat the earth receives?

(*a*) Bend a piece of cardboard so as to make a square tube one square inch in cross-section and one foot long, as shown in Figure 22.

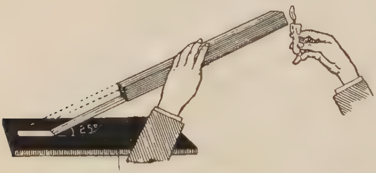


Fig. 22

Paste a narrow strip of heavy cardboard to one of the inside walls of the tube so that the strip extends 6 inches beyond the end of the tube. Darken the room and hold a candle flame or a flash-light at the upper end of the tube. Incline the tube, resting the end of the narrow strip on the table and having the tube at about a 25-degree angle with the table top, as in the figure. This will allow a beam of light one inch square to strike the table. Make the outline of the spot of light caused by the beam which passes through the tube. Also note the brightness of the spot.

(*b*) Now change the position of the tube so that the beam of light strikes the table at an angle of about 75 degrees. Be sure that the end of the narrow strip of cardboard just touches the table, as in Figure 23. Mark the outline of the spot of light, and also observe its brightness.

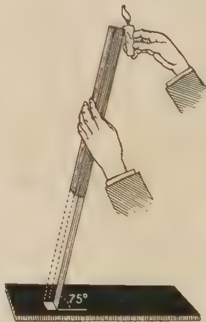


Fig. 23

Compare the sizes of the two spots obtained in (*a*) and (*b*), measuring them and determining the area of each.

You see that the same beam of light covers less space when the angle at which it strikes the table is greater. You can also

see that the spot is brighter when the beam strikes the table more nearly vertically. There is more light on the same area.

Exercise 14. The figures in Experiment 5 represent the sun and the earth. Figure 22 shows the angle of the sun's rays in winter; Figure 23, the angle in summer. What is true about the amount of light and heat received from the sun at noon on a summer day compared with that received at noon on a winter day? Explain.

There is another point which you must consider in explaining why the angle of the sun's rays affects temperature. As the rays of the sun come through the air toward the earth, they lose some heat to the air, because some of the rays strike particles of air. Dust particles in the air also help to stop the rays, and thus all of the heat does not reach the earth. Now in winter the rays come at a great slant and must, therefore, pass through a longer column of air than in summer when they are more nearly vertical. As a result they give up more of their heat to the air in winter, and so have less heat left when they strike the earth. In summer the rays are more nearly vertical, and, having to pass through a shorter column of air, they bring more heat to the surface of the earth.

Exercise 15. From Exercise 11 and Experiment 5 state two reasons why summer is hotter than winter in the Northern Hemisphere.

PROBLEM 6: HOW DO WE GET CORRECT TIME?

The earth is our best clock. The movements of the earth not only determine day and night and the seasons, but also our time. The most regular movement of any body which we know is the rotation of the earth on its axis. It varies less than one one-hundredth of a second in a thousand years when measured by the stars. This movement of the earth is, therefore, the best clock in the world, and it is actually used to keep correct time.

"What time is it?" is a question which you hear many times every day. Ordinarily you look at a watch or clock, or perhaps at the sun for the answer; very seldom do you find that two

clocks or watches exactly agree. In ordinary life it makes little difference whether two watches are exactly correct, but on a railroad, for example, a difference of a few seconds may mean the loss of life. Why? Here, as in certain other affairs of life, it is necessary to have correct time.

Naturally you ask, Where do we get correct time? If you asked the question of many people, a majority would say that we get it from the Western Union or the Naval Observatory. But suppose you ask, Where do the Western Union and the Naval Observatory get time, and how are they sure that their time is correct? Most of us would answer, "from the sun." But few of us could tell just how the sun is used to tell time, and few of us know that the astronomers measure time very accurately by observing the stars.

Fig. 24. Longitude and Latitude

Longitude is measured in degrees east or west of the meridian which passes through Greenwich, called the *prime meridian;* latitude is measured in degrees north and south of the equator. What are the longitude and latitude where you live? What are the latitude and longitude of the North Pole?

A day is the period of one rotation of the earth. Since our daily activities depend largely upon daylight and darkness, we use *solar time*, or sun time. Sun time is found in this way: a telescope is set in a true north and south line, that is, on a *meridian* (Figure 24). The exact time when the sun appears in the middle of the telescope is recorded. This is noon. On the next day the passing of the sun over the meridian is again recorded. The time between the two records is the *true solar day*. The average of the solar days for a year is called the *mean solar*

day. This we divide into 24 hours, each hour into 60 minutes, and each minute into 60 seconds.

Time varies with the longitude. The *mean solar time* varies at places having different longitudes. If it is noon at Chicago, you know that it is afternoon in New York and forenoon at Denver. It is 25,000 miles around the earth at the equator, and since it takes 24 hours for the earth to make one rotation, the mean solar time must vary one hour for a little over 1000 miles, or about one minute for 17 miles at the equator. In the latitude of 40 degrees north (40°N), from 12 to 13 miles make one minute's difference in the time. Since there are 360 degrees in a circle, you see that to go once around, the earth moves through 360 degrees. This rotation requires 24 hours. Therefore the earth moves through 15 degrees per hour. If, then, it is twelve o'clock (noon) at a place having 0° longitude, it would be one hour later at a place having 15° East longitude (Figure 24).

Because the local times vary, there would be great confusion if everyone used local mean solar time. To avoid this confusion, and particularly to help the railroads in making their schedules, our government in 1883 adopted *Standard Time*. The 75th meridian, passing through Philadelphia, was made the starting point, and all places east and west within one-half hour of the local time of this meridian adopted the local time of the meridian. This is the Eastern Time Belt (Figure 25, page 32). West of this belt is the Central Time Belt. Going westward, we find the Mountain Time Belt and the Pacific Time Belt. This division of the United States into time belts makes it necessary for travelers going westward to set their watches back one hour whenever they cross from one belt into another. If you were making a journey from San Francisco to New York, how many times would you set your watch ahead one hour?

Exercise 16. Write one question for each paragraph in this problem in such words that the correct answer to your question will give the main idea in the paragraph.

Exercise 17. How do the mean solar time and standard time of a place 5 degrees west of Philadelphia compare with the mean solar and standard time at Philadelphia? (See Figure 25.)

Exercise 18. Explain how it is possible that news of the signing of the armistice following the World War reached Washington, D. C., before 9:00 A.M., although it was 11:00 A.M. when it was signed in France. (See Figures 24 and 25.)

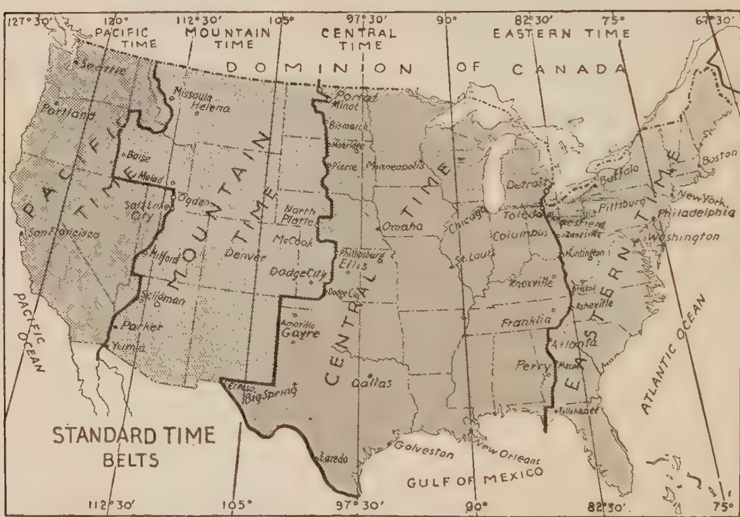


Fig. 25. Time Belts of the United States

Each belt extends about $7\frac{1}{2}$ degrees east and west of its meridian. This meridian is exactly 15 degrees from the meridian of the adjoining belt. The boundaries of the different belts are irregular because it was found more convenient in operating the railroads to change times at certain stations.

Review Exercise on Entire Unit. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly, or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit I and see if you can give satisfactory answers to each of the problems of this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT I

1. Make a list of all forces you can think of which (*a*) help to break rock into soil; (*b*) which move soil from place to place.

2. Name as many forms of land, like mountains, hills, and islands, as you can.

3. How many different kinds of bodies of water can you list?

4. How do the lengths of days and nights in the Southern Hemisphere vary with the seasons in the Northern Hemisphere?

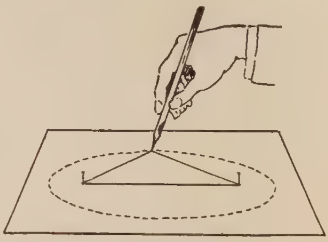


Fig. 26. How to Make an Ellipse

5. To draw an ellipse, which is the shape of the orbit of the earth, take two tacks, a string, and a pencil (Figure 26) and draw one. Change the distance between the tacks and try again. Is the second ellipse of the same shape as the first?

6. At Hammerfest, Norway, which is located at 71° N, the sun never sets from May 13 to July 8, and never rises from November 18 to January 23. Explain. (Figures 20 and 24 will help you.)

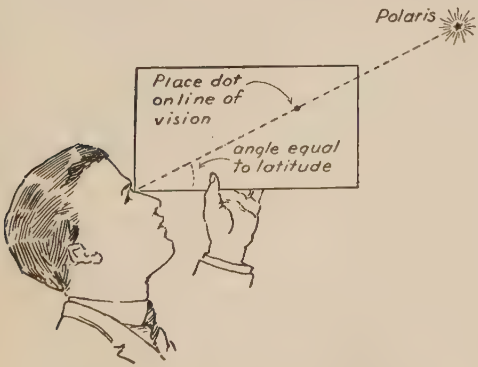


Fig. 27. How to Find Latitude

7. On what hour of the day and what day of the year do you cast the shortest shadow? Why? (See Figure 21.)

8. When Peary was at the North Pole, in what direction did he look to see the North Star?

9. Moonlight is really sunlight. Explain.

10. Hold a watch face upward, and point the hour hand toward the sun. Half way between the hour hand and the figure 12 (or XII) is nearly south. You can determine direction in this way. Why?

11. Hold a piece of cardboard in a horizontal position as shown in Figure 27 and look at the North Star with one eye closed.

Mark a point along the line from the eye to the North Star. Draw a line through this point and the corner of the cardboard from which you sight. Measure the angle. This gives you the approximate latitude of your place. Why?

12. Stick a long pin near the middle of the south edge of a sheet of paper which is in a position to receive sunshine throughout the day (Figure 28). Beginning at 8 o'clock A. M. mark the shadow of the pin every hour. How could you use this to tell time? To tell direction?

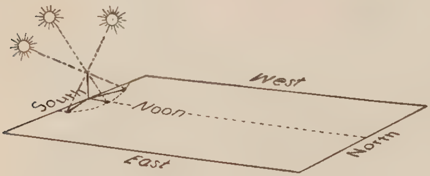


Fig. 28. A Miniature Clock and Compass

13. How was the Arctic Circle located? The Tropic of Cancer?

14. If you traveled around the earth from west to east in 90 days of 24 hours each, how many times would you see the sun rise?

15. How do you know that the earth's axis is inclined?

16. How is the number of days in a year determined?

17. The North Star is a little over one thousand million million miles away. The light from it travels at the speed of 186,000 miles per second. Suppose the star suddenly ceased to give light. For how many years would we on the earth still see its light?

Note to the Student. A little knowledge about any subject makes one want to know more about it. This unit has suggested to you many topics, projects, or problems which you may wish to study further.

Following Unit XVII, on page 513, you will find a list of References and a Guide For Additional Study about the earth and the heavenly bodies. A similar list of references will be found for each unit of the book. Turn to the list on Unit I, and select a book or pamphlet which you wish to read. Select also one of the topics or projects which are listed following the references. Spend your spare time making a careful study of this topic or project.

UNIT II

WEATHER AND CLIMATE

Preliminary Exercises

1. Make a list of words which you can use to describe weather. In a parallel column make a list of words which describe climate.

2. In what ways has weather affected your life? Climate?

3. Keep a daily record of the weather. (See Preliminary Exercise 12, page 2.) Use the form below.

Record of Weather

DATE	TEMPERATURE	FEELING OF AIR	SKY	DIRECTION OF WIND
10–4–25	70	Damp	Cloudy	S. W.

If you have a barometer in the room, add another column to the table and enter the barometer reading. From the daily record of the weather which you have kept, state your conclusions regarding the relations between any of the factors listed in the table.

4. Make as large a list as you can of the different means by which people predict weather. When you have studied this unit, check those which seem to be correct, stating your reasons.

5. Get the daily forecasts from the newspapers, paste them neatly in your notebook, and make a memorandum beside each, indicating any errors which the weather-man makes. Do this for several weeks. What percentage of the forecasts is correct?

6. Have you learned of any relation between the movements of the earth and weather or climate? What? Explain.

7. In what respects would your life today be different if you lived in a very cold climate? In a hot climate?

8. The earth has changes in weather and climate, while no such changes occur on the moon. Explain.

9. State two reasons why the temperature of the surface of the earth varies in your region from day to day.

THE STORY OF UNIT II

In Unit I you became acquainted with the earth as a member of the solar system. You found that the composition and movements of the earth constantly influence your life. Nature has provided many forces and materials which determine how you live and what you do every day.

Courtesy Pathé Films

Fig. 29. Life in a Cold Climate

Far from the equator, where the rays of the sun are always slanting, the temperature is cold. Life is very primitive here. Clothing is made of skins and furs. On hunting trips the natives often make shelters of ice and snow, called igloos. The hunters in this figure are packing snow into the cracks between the blocks of ice used to make the shelter.

No forces of nature affect you more than the *weather* and *climate* of the region in which you live. Even from the earliest days of man's existence on earth these great forces have determined man's dwelling place as well as his activities and mode of living. The kinds of plants and animals that exist, the kind of food you eat, the clothes you wear, the type of houses in

which you live, the work you do, the way you travel, your health, the games you play; in fact, practically everything you do and have depends upon the changes in weather and upon the climate of your environment.

Of these two factors climate is the more important to you. To appreciate this you need only to think how different your life would be if you moved to a different climate. Far in the North you would live like the Eskimos (Figure 29). You would dwell in houses of ice or in underground huts, wear clothes made of the skins of animals (Figure 155, Unit VI), and live largely on fish and meat. Again, if you moved to a very warm climate, you could live out-of-doors the year round, plants would grow abundantly in your surroundings, and your food supply would be entirely unlike that of the Eskimos (Figure 30). And in the temperate regions you would find life far different from that in the cold and hot climates.

Underwood and Underwood

Fig. 30. Where the Rays of the Sun Are More Direct

How different is life in a warm climate from that shown in Figure 29—and largely because of the difference in the angle of the rays from the controlling body of the solar system, the sun. Here clothing is very meager, many kinds of tropical plants grow, and the shelters are built of plant limbs, stems, and leaves.

If you wish to understand these great forces of weather and climate, you must remember that the sun furnishes the earth with heat. The amount of heat, as you know, varies with the angle of the sun's rays, with the length of day and night, and with the condition of the sky. The latitude of a region is, therefore, an important factor in determining the *temperature* of a region. In the far North or far South, where the days are short in winter and the sun's rays strike the earth at an extreme slant, the sun gives little heat. The climate and weather are cold in such latitudes. Similarly, in the tropical regions, where the days are long and the sun's rays are more nearly vertical at all times, the climate and weather are hot. Between these two regions the temperate climates exist. Thus you see that temperature is one of the important factors of weather and climate.

Now you must not think that temperature is the only factor of weather and climate. We may have hot or cold climates and hot or cold weather, but we may also have wet or dry climates and wet or dry weather. The air is *porous*, much like a sponge. This allows water to *evaporate* from the earth, that is, to change to a gas and mix with the air. However, it does not always remain in the air. Sometimes it turns to small droplets, forming clouds, or it may fall to the earth as rain, mist, snow, or hail. Thus at different times we may have clear weather, cloudy weather, and rainy or snowy weather. Since the amount of water which evaporates into the air and the amount of water which comes out of the air vary in different places, you see that a region may have a wet, a dry, or a damp climate.

Though changes in temperature and moisture conditions largely determine the climate and weather of a region, there are several other factors which must be considered. One of these is the *altitude* of a region. Thus a high mountain has a climate and weather unlike that of a valley on either side of the mountain. Another influence is the presence of large bodies of water which may affect both the temperature and the amount of

moisture in the air. For example, the climate of cities on the eastern shore of one of the Great Lakes differs noticeably from the climate of cities on the western shore, even though they are in the same latitude. A third factor is the presence of warm or cold ocean currents, as you recall from your study of geography. Still another is the general movement of the air on the surface of the earth, and the local movements, or local winds. And one more important factor is the nature of the surface of the earth. You probably recall, for example, that the presence of mountains causes a dry climate in a region on the opposite side from which the general winds come. The desert region in the southwestern part of the United States is a good example of the effect of mountains on climate and weather.

The causes of weather changes and of climate present many interesting problems. Let us turn to some of these and learn to understand our environment better.

PROBLEM 1: WHY DOES THE TEMPERATURE OF THE AIR CHANGE?

Probably the most common of all words used to describe weather and climate are those which refer to the temperature of the air, such as hot, warm, moderate, cool, and cold.

The sun is the source of the earth's heat. You recall that the sun is the source of the heat which causes changes in temperature. (See page 27.) You will also remember that the sun does not send heat to the earth, for heat cannot pass through an empty space. Since the space between the sun and the air covering of the earth contains no material, heat cannot come through it. This space is much like that between the two walls of a vacuum bottle: most of the air has been removed, and therefore little heat is allowed to enter or to get out of the bottle. The sun does send waves of light and *radiant energy* through the space between the sun and the earth. It is this radiant energy which produces the heat when it strikes the air and the surface of the earth.

Experiment 6: How is the earth warmed by the sun?

Obtain two test tubes. Partly cover one of the test tubes with smoke by rotating it in a candle flame. Place the two tubes in an upright position (Figure 31) and nearly fill each tube with water. Take the temperature of the water in each tube. Now bring the tubes into the direct sunlight; leave them there for 15 minutes. Again take the temperature of the water and record the readings. Remove the apparatus from the sunlight, allow it to stand for 15 minutes, and take the temperature of the water in each tube. What do the results show?

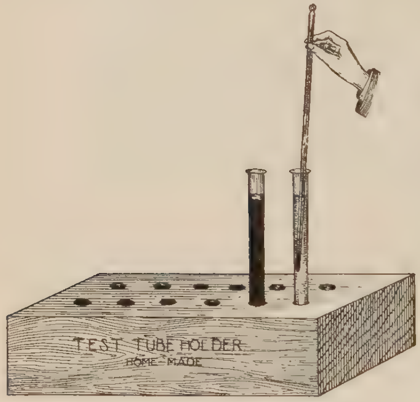


Fig. 31. Radiant Energy Apparatus

The dark tube has been covered with smoke. Both tubes contain the same volume of water. In which tube will the water become warm the more rapidly when the tubes are exposed to the rays of the sun?

Only a part of the radiant energy from the sun changes to heat when it passes through a material like air, colorless glass, or water. But when it strikes a material which holds it or *absorbs* it, like soil or the black deposit on the test tube, much of the radiant energy is changed to heat. A clean windowpane is warmed but little by the radiant energy from the sun, but the floor inside the room, where the same energy is absorbed, is warmed considerably.

Exercise 1. On a clear day a sidewalk feels warmer than the air above it. Explain.

All materials are not equally warmed by the sun. Let us now try to understand how the temperature of the air depends upon the kind of material on the earth's surface. The light and radiant energy from the sun may be *transmitted* through

transparent materials like glass or air; they may be *reflected*, in part, by water, light-colored materials, or shiny surfaces; or they may be almost entirely *absorbed* by dull, dark-colored materials (Figure 32).

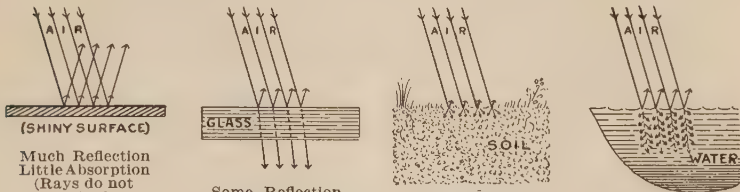


Fig. 32. Radiant Energy May Be Reflected, Transmitted, and Absorbed

The arrows from above represent radiant energy from the sun. The air allows much of the energy to pass through it and to strike the different materials on the surface of the earth. The arrows pointing upward show reflected radiant energy. The length of these arrows shows roughly the amount of radiant energy reflected. Which substance becomes hottest on the surface?

Exercise 2. Will the same amount of sunshine cause equal changes in the temperature of the air above black soil, clay, rocks, and sand? Explain your answer. Will these materials lose heat at the same rate? (See Experiment 6.)

If a material is partly transparent, like water, the radiant energy goes some distance into the water before it is changed to heat. Thus more material must be heated than in cases where the energy is nearly all absorbed at the surface.

Exercise 3. From Figure 32 give one reason why a large body of water does not become warm in the spring as quickly as the surface of the land around it does. (There are other reasons why this is true.)

A second reason why the air above different materials of the earth's surface varies in temperature is the fact that all materials do not change equally in temperature for the same amount of heat absorbed. Every kind of material has a different *capacity* for heat. You can think of two different materials of

the same weight as two boys of the same size. Compare the heat to the amount of food eaten by the two boys, and the temperature to the satisfaction which they feel in eating. If they eat the same amount of food, one may be but little satisfied, while the other may be more nearly satisfied. Similarly, two different materials having the same weight may receive the same heat from the sun with the result that one becomes but little warmer, while the other, which requires only a small amount of heat to make it hot, becomes much warmer.

Exercise 4. Review your study of the problem up to this point and state two general reasons why the temperature of the air varies. (Remember that the air is heated by contact with the surface of the earth.)

Hours of sunshine and angle of sun's rays affect temperature. Two additional reasons why the air is not at the same temperature at all times and in all places you will recall from Unit I. The first is the length of time during which the sun shines. This varies with the condition of the sky and the season of the year. The second is the angle of the sun's rays, which depends upon the latitude and which changes from hour to hour during the day, and from season to season.

Altitude must be considered. A fifth cause of difference in temperature is the altitude of the earth's surface. The air covering of the earth keeps the heat of the earth's surface from escaping rapidly. It acts like a blanket to hold the heat near the surface of the earth. At high altitudes the air is thin, and the heat can easily escape as radiant energy. At low altitudes, such as in deep valleys or near sea level, the air is packed more closely together because of the weight of the air above it, and the heat cannot escape so rapidly. The temperature is about one degree colder, as measured on our ordinary thermometer, for every 300 feet above the surface of the earth. If it were not for the air, the temperature of the earth would be so hot during the day, and so cold during the night, that no living thing could exist. The earth's surface would be like the moon's surface, just a mass of rock.

The five causes mentioned not only determine the temperature of the surface of the earth, but they also produce changes in the temperature of the air. This is true because the air is in constant contact with the earth and receives most of its heat from the earth.

Also, you must bear in mind that the air is constantly moving and that the warm or cold air over one place may move to

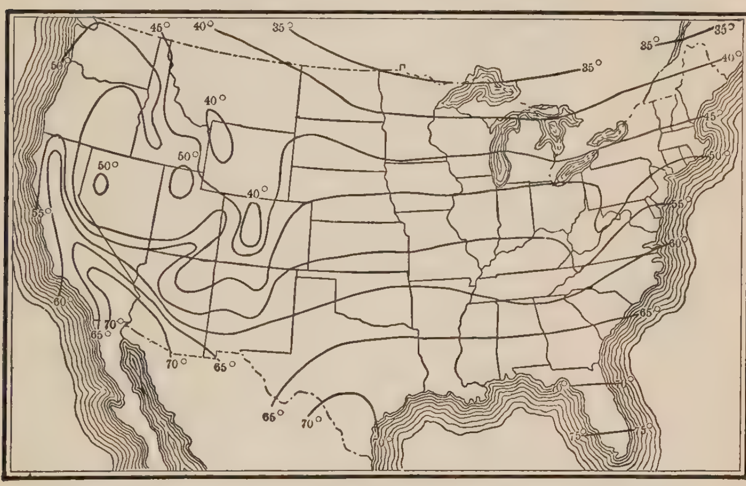


Fig. 33. Heat Belts of the United States

The small numbers on the solid black lines show the average annual temperature at places through which the lines pass. The map is called "The Mean Annual Temperature Map" by the Weather Bureau. What is the mean annual temperature where you live? If your location is not exactly on one of the lines, you can estimate the temperature.

another place, causing changes in temperature. Records which have been kept by the Weather Bureau show the principal heat belts of the United States to be those in Figure 33.

Exercise 5. If the air were not a freely moving material, it would not be warmed greatly, even on a summer day. Explain.

Exercise 6. Make a statement outline, like that used in Exercise 9, page 23, which explains "Why the Temperature of the Air Varies."

PROBLEM 2: HOW AND WHY ARE CHANGES IN TEMPERATURE OF THE AIR MEASURED?

Galileo invented the thermometer. In order to get an accurate way to measure changes in temperature Galileo, an Italian scientist, made the first *thermometer*, in 1592. ("Thermometer" comes from two words, *thermos*, meaning heat, and *meter*, meaning measure.) His device looked something like the apparatus shown in Figure 34. By bringing a hot object near the container, the air inside was warmed and expanded, driving the liquid down the tube. The distance to which the liquid moved indicated whether the object was hotter or colder than some other object held near the container. The instrument was, of course, not very accurate.

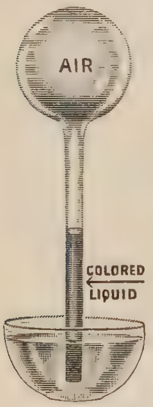


Fig. 34. The First Thermometer

This device did not measure temperature in degrees, but it did make it possible to know if one object was hotter than another or when two bodies were at the same temperature.

Our present-day thermometers use mercury or alcohol. Since Galileo's time different kinds of thermometers have been made. The ones which we use today for taking the temperature of the air are the mercury and alcohol thermometers. Usually some coloring matter is added to the alcohol so that it can be seen more plainly.

Exercise 7. Examine a thermometer carefully. Is the wall of the upper part of the thermometer thick or thin? How large is the tube inside? Does it connect with the bulb at the lower end of the tube? What part of the bulb and tube is filled with the liquid? Why must all air be removed from a thermometer? What is the room temperature? Warm the bulb with your hand and observe whether the thread of liquid in the tube moves. Place the bulb in cold water. How does this change the height of the liquid?

Write a paragraph in which you explain how the thermometer works. Be sure that you have included the answers to all the questions of this exercise.

If you examine different thermometers, you find that they are not all marked the same way. There are two common scales or methods of marking. The common thermometer which is used in your homes and at the Weather Bureau is called the *Fahrenheit* thermometer. It was first marked by the German scientist, Fahrenheit, in 1714. In many countries and everywhere in science laboratories the *centigrade* thermometer is used.

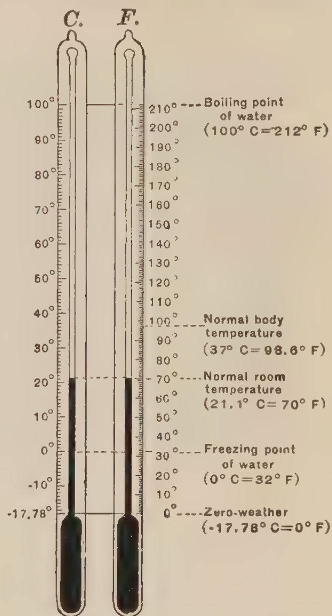


Fig. 35. Comparison of Centigrade and Fahrenheit Scales

From Figure 35 you see that zero degrees on the centigrade (0°C.) is the same as 32 degrees on the Fahrenheit (32°F.), and that 100° on the centigrade (100°C.) is the same as 212° on the Fahrenheit (212°F).

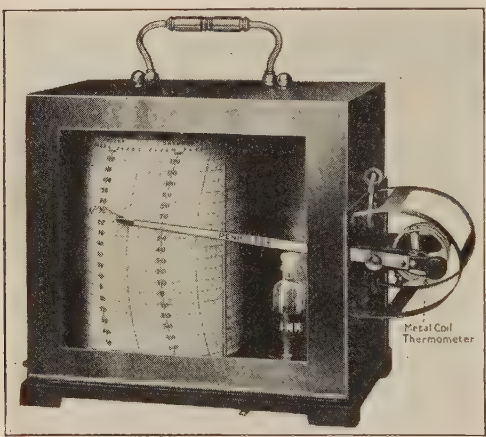
Since there are 180 degrees between the boiling and freezing points of water on the Fahrenheit scale and only 100 degrees on the centigrade scale, one degree centigrade is $\frac{9}{5}$ times as big as one degree Fahrenheit. For the same difference in temperature there are $\frac{5}{9}$ as many degrees on the centigrade as on the Fahrenheit or $\frac{9}{5}$ times as many on the Fahrenheit as on the centigrade. You can change the temperature on one scale to the corresponding temperature on the other, thus:

$$(a)\quad 212°\text{ F.} = (212 - 32) \times \tfrac{5}{9} = 100°\text{ C.}$$

$$(b)\quad 100°\text{ C.} = (\tfrac{9}{5} \times 100) + 32 = 212°\text{ F.}$$

Exercise 8. Suppose you are in a country where the centigrade thermometer is used and the thermometer reads 38°. Find, by studying Figure 35, what temperature a Fahrenheit thermometer would show. Prove your answer by calculation.

Records of temperature are important. If you go to a Weather Bureau station, you may see both the mercury thermometer and a thermometer called the thermograph (Figure 36), which makes a record of the temperature. Records of the temperature at all times and in all parts of our country are accurately kept by the Weather Bureau. These furnish a part of the information which the Bureau needs to predict weather and to determine the average temperature of every region. In later problems you will see the great importance of such records.



Courtesy Taylor Instrument Co.

Fig. 36. A Recording Thermometer

Inside the cylinder is a clock which makes the cylinder and the record sheet revolve once in a week. The metal coil is the thermometer. It opens slightly when warmed, causing the pen to move upward, and closes when cooled, causing the pen to move downward. Thus an irregular line is drawn on the sheet, giving a record of the temperature for an entire week.

PROBLEM 3: WHAT CAUSES CHANGES IN RAINFALL?

Water evaporates from the earth. Water is always evaporating from the surface of the earth and going into the air. You have often noticed how quickly the streets or roads dry after a rain. Soils dry out and become parched in the hot sun. Grass and other vegetation dry up in the summer time as they lose their water. Everywhere on the earth liquid water changes to water vapor and enters the air as an invisible *gas*.

The amount of water which evaporates from the surface of the earth depends largely upon the temperature. A plowed field, a ball-field, a street, or a tennis court will dry very rapidly when the "sun is hot."

Experiment 7: Does the rate at which water evaporates into the air depend on temperature?

Place equal amounts of water in two tin cups. Mark accurately the level of the water in each cup. Stand one in a cool place and the other in a warm place (in the sunshine or over a warm radiator). On the next day examine each vessel and find if water has evaporated. From which vessel has water evaporated the more rapidly? Why?

Water evaporates more rapidly when the temperature is high than when it is low. This is true for two reasons: first, heat causes water to change to water vapor, and second, warm air can hold more water vapor than cold air can. The amount of water vapor in the air is spoken of as *humidity*. Air is *humid* when it contains much water vapor.

Water vapor condenses when air is cooled. If air which contains water vapor is cooled enough, some of the water vapor will come out of the air and form liquid water. We say that vapor *condenses* when it changes to a liquid.

Experiment 8: To cause water vapor to come out of the air, or condense.

Pour a little water into a tin cup or bright metal vessel. Drop a few small pieces of ice into the water and stir the mixture. Watch the outside wall of the vessel. What do you see? How do you explain the result?

Exercise 9. Explain why drops of water form on the outside of a pitcher of ice water when it stands in a warm room.

Air that is warmed near the surface of the earth is forced upward by the colder air around it. As it rises it is cooled, and the water vapor condenses into little drops, forming *clouds*. Also, if the winds bring humid air to a cooler region, clouds

are formed. If little condensation takes place, the clouds are light-colored, but if there is a great amount of condensation, the clouds are dark. The very dark rain clouds which appear just before a storm contain many droplets of water. At very high altitudes, where it is very cold, the drops may freeze,

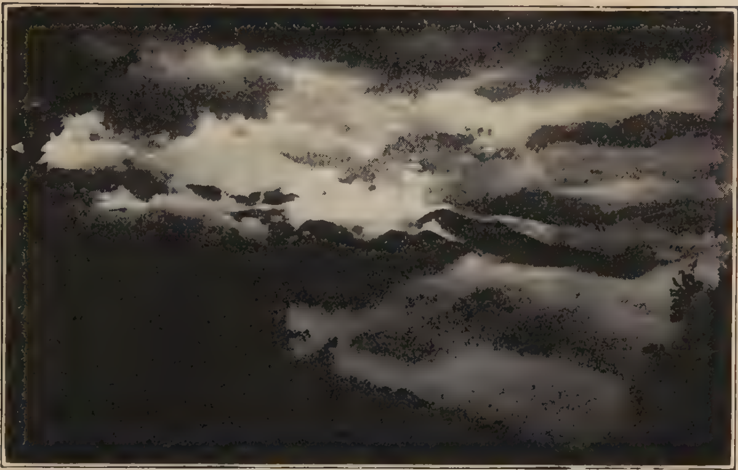
Courtesy F. Ellerman

Fig. 37. Cumulus Clouds

These dome-shaped clouds are commonly seen in summer. Such clouds often precede a thunderstorm. They usually have a flat base and are only about a mile above the earth.

forming ice-crystals. Four of the more common kinds of clouds are shown in Figures 37, 38, 39, and 40.

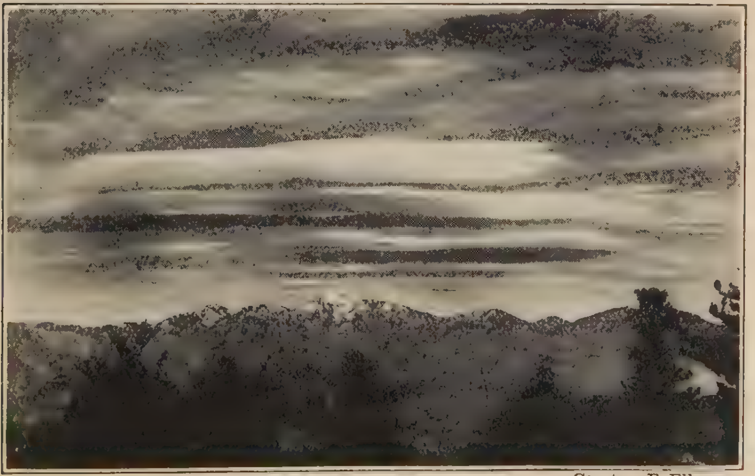
When humid air is cooled to a great extent, much condensation occurs. The droplets become so numerous that they form into larger drops of *mist* or *rain*. Rain drops are too heavy to float in the air, and they fall to the earth. Thus it often happens that a south wind which contains much water vapor brings rain. If the wind comes northward at a considerable speed, and is forced upward by the cooler air around it, it becomes cooler very rapidly. Thus clouds and rain may form quickly.



Courtesy F. Ellerman

Fig. 38. Nimbus Clouds

These are the rain clouds. They are usually less than a mile above the earth. Note their "stormy" appearance.

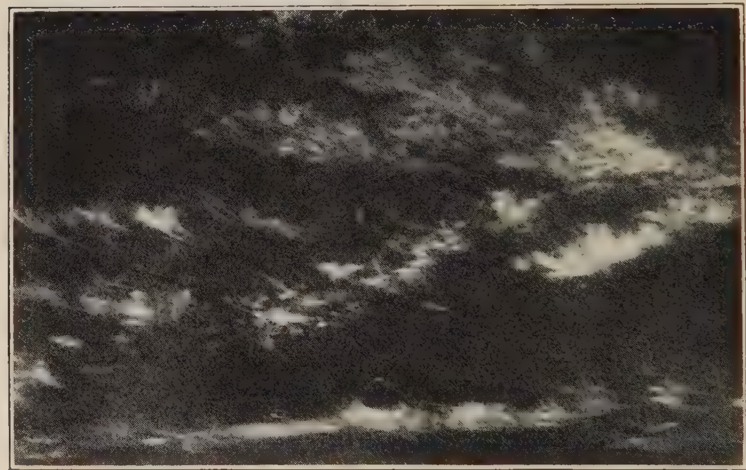


Courtesy F. Ellerman

Fig. 39. Stratus Clouds

These layer-like clouds are often so low in the sky that they hide the tops of small mountains or large hills. They sometimes remain in the sky for several days and frequently bring long, steady rains.

Rain drops in falling may pass through layers of air which are below the freezing point. The drops may then be frozen into pellets and fall to the ground as *sleet*, or they may be carried upward and downward several times by air currents. In the latter case on each trip a layer of ice is added until they



Courtesy F. Ellerman

Fig. 40. Cirrus Clouds

Several miles above the surface of the earth cirrus clouds may often be seen. They look like feathers or plumes and are made of ice-crystals. The light from the sun and moon can pass through them because they are so thin. These ice-crystals produce the halos or rings frequently seen around the sun or moon.

become large *hailstones* and fall to the earth. Figure 41 shows the appearance of some large hailstones. Figure 42 is a section drawing made from a hailstone cut in half.

When the temperature of a region where condensation occurs is at 0° C. or 32° F., or below this temperature, the vapor separates from the air, changing to a solid in the form of *snow* crystals (Figure 43). Of course this can happen only during the colder seasons, except at very high altitudes.

Dew and *frost* are other forms of water which come from the air. When the weather is clear and the night is cool, the

earth loses its heat very rapidly. The water vapor in the air near the surface of the earth is condensed on the grass or ground, or on other materials near the earth. Why? If the temperature is above 32° F., the vapor condenses, forming dew, but if the temperature is below freezing (0° C. or 32° F.), the moisture will be deposited as frost.

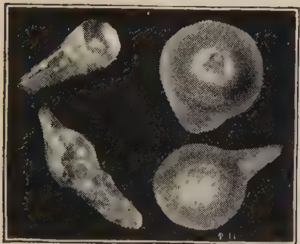


Photo by W. A. Bentley

Fig. 41. Hailstones

At the left are two hailstones which fell during a thunderstorm; at the right two winter hailstones are shown. Compare the hailstones at the right with Figure 42.

Fig. 42. Layers in a Hailstone

Exercise 10. One often hears statements like those listed here. Explain why each of these ideas is incorrect. (1) "Snow is frozen rain." (2) "Dew comes out of the ground." (3) "Frost is frozen dew." (4) "The dew is falling." (5) "Dark clouds are made of smoke."

Photo by W. A. Bentley

Fig. 43. Frozen Water Vapor

Note that six seems to be the favorite number for snow. All of these crystals have six sides, six points, or six lines leading out from the center.

The amount of rainfall varies in different places. From your previous study you see that the amount of rainfall must depend upon the temperature and humidity of the air. These two conditions are very closely related. A high temperature on the surface of the earth causes the water in the soil, on vegetation, and in the bodies of water to evaporate quickly.

At the same time the air in contact with the surface of the earth is warmed and can take up more water vapor. When such air is cooled, a large amount of rainfall will result.

Wherever the changes in temperature and humidity are great and occur frequently, the rainfall is heavy. The torrent-like rains of the tropical regions illustrate best the preceding statement. Here the surface of the earth and the air become greatly heated every day. The warm, humid air rises into the cooler layers above, and heavy rains result almost every afternoon. These changes in temperature and humidity may also be brought about by the *winds*, or movements of air along the surface of the earth. For example, a wind blowing over a warm valley or body of water may become laden with moisture, and then move up a mountain slope and become greatly cooled, the result being a heavy rainfall.

The last statement suggests that the nature of the surface of the earth is another important factor in rainfall. The *topography* of the earth, that is, the presence of valleys, rivers, lakes, mountains, plateaus, oceans, and all other land and water forms, influences the temperature and humidity of the air. Because the surface of the earth is composed of different materials, and because of the differences in altitude, the earth is unequally heated by the sun. As the air moves over these different regions, its temperature changes. Also, the humidity of the air changes because of the amount of evaporation which may take place over the different regions. Thus a warm wind blowing over a warm body of water takes up great amounts of water. This air may rise to cooler layers directly above; it may be carried by the wind to regions of higher altitude; it may be moved to other parts of the surface of the earth which are cooler. Such changes produce great rainfall.

Just as great rainfall depends upon the factors mentioned, so does little rainfall depend upon them. When cool air, which has lost much of its water vapor, moves to warmer regions, it is able to take up more water vapor. In the United States you find one excellent illustration of this. As the warm,

moist air from the Pacific moves over the mountains in its eastward movement, it drops much of its moisture in the form of rain and snow. As it comes down the eastern slope of the mountains, it is warmed, and its capacity for holding water is increased. It therefore takes up water vapor from the land, producing the vast desert region just east of the Rockies.

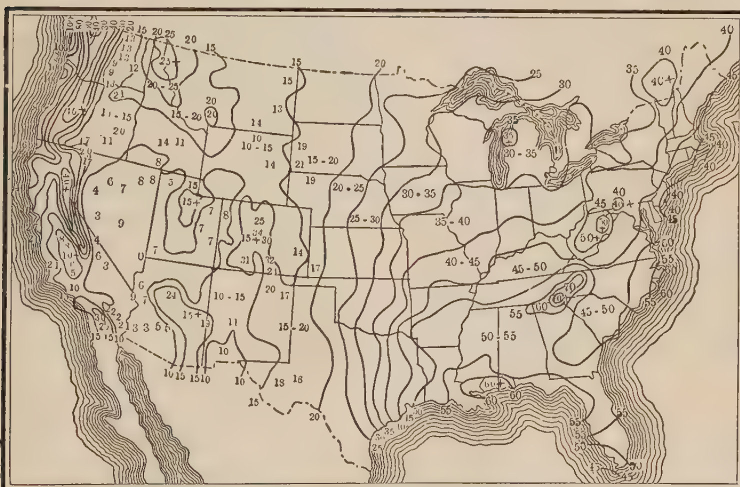


Fig. 44. Rainfall in the United States

This map gives the number of inches of rain which fall in one year. The figures are the average, or mean, for several years. Such a map is called "The Mean Annual Rainfall Map."

Exercise 11. Examine the map carefully (Figure 44), and answer the following questions:

1. Where are the regions of least rainfall? Explain why there is little rainfall in these areas.
2. Why is the rainfall so great along the northwest coast?
3. How do you account for the heavy rainfall in eastern Tennessee?
4. What is the average rainfall in your region, and how do your agricultural industries differ from those of other regions because of the difference in rainfall?

PROBLEM 4: WHY DOES THE WIND BLOW?

You have learned that the movement of air, or wind, is an important factor of weather and climate. Wind is always changing direction and speed. Sometimes it brings "muggy" weather and rain; at other times it gives us cool and fair weather; at still other times it carries with it snow or sleet. What causes it to move and what determines its speed?

Air is material. If you consider the *properties*, or characteristics, of air, you can explain why the wind blows.

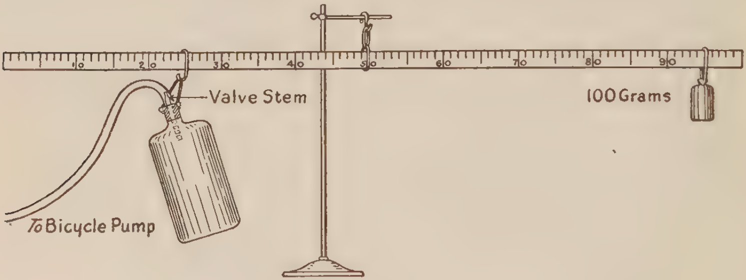


Fig. 45. Weighing Air

Air seems to have no weight, because it is all around and inside us. If we lived in water instead of air, water would seem to have no weight, and yet we know it has. So has air.

Experiment 9: Has air weight?

Balance a bottle of air, fitted with a very tight stopper, a delivery tube, and a bicycle-tire valve, on a meter stick, as in Figure 45, or on a good balance. Now pump air into the bottle with a bicycle- or automobile-tire pump. Be careful not to change the positions of the weight and bottle on the stick. (If a tack is driven through the string into the stick, the position of the bottle will not change.) Remove the pump. Does the weight still balance the bottle? How do you explain the result?

Exercise 12. A cubic foot of air weighs approximately 1.29 ounces. What is the approximate weight in pounds of the air in your schoolroom?

Experiment 10: Does air exert pressure?

(*a*) Tie a piece of dentist's rubber dam, a piece of a rubber balloon, or some thin bicycle inner tubing over a funnel or a thistle tube which has a short rubber tubing connected to the stem (Figure 46). (The top of the tube or funnel should be ground by rubbing it on sand paper until it is level.) Hold the apparatus in a vertical position with the rubber dam facing upward. "Suck out" some of the air, and tie a string around the rubber tubing to keep the outside air from going back through the tube into the funnel. What has happened to the rubber dam? There must be some force which stretches the rubber. Turn the apparatus on its side, and upside down. Do you find that the force acts in all directions?

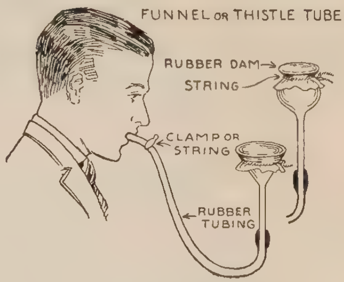


Fig. 46. Air Pressure

The ancients said "nature abhors a vacuum." What they meant to say is that the air pressure exerts a force which tends to push air into any space from which all or a part of the air has been removed.

(*b*) Remove the string from the rubber connection and allow the air to enter. What happens? Place some vaseline on a glass plate large enough to cover the mouth of the funnel, and hold the plate securely against the rubber. Again "suck out" some air and tie the string around the rubber tubing. Does the rubber bulge inward? Was the bulging in the first part of the experiment due to "suction"? Slide the glass plate aside and note that the rubber is forced inward. The force which causes the bulging must be from the outside. Why? (If you have an air pump and bladder glass [Figure 47], you can show this air pressure in a much more striking way.)

Air pressure is all around you, pushing equally in all directions, as the experiment clearly shows. You are not conscious of it, because the pressure is the same in all directions and because there is air inside your body as well as outside. This pressure is due to the weight of the air, and is approximately

15 pounds to the square inch on every object at the surface of the earth.

Exercise 13. What is the total force of the air on a garden plot 40 feet long and 25 feet wide?

Differences in air pressure cause winds. It is now easy to understand how a difference of pressure in different places causes the air to move. If the pressure in one place is fifteen pounds on a surface one inch square, while in another place it is greater, some of the air from the latter place will move toward the former place, just as the air outside the rubber dam tried to move into the tube where the pressure was lessened by the removal of some air. The slightest difference in pressure will cause some movement of the air, for, being a gas, air moves freely. And if the difference in pressure is great, the movement of air from one place to another is rapid. Such movement of the air is called *wind.*

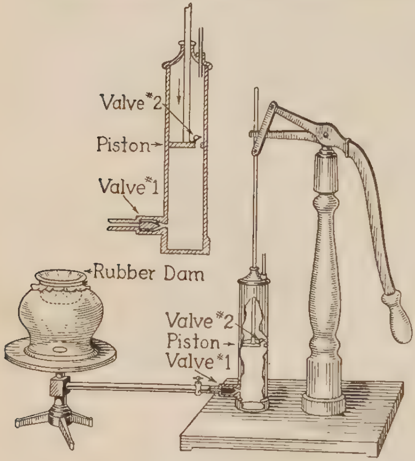


Fig. 47. Air Pump and Bladder Glass

As the piston moves down, Valve 2 opens and Valve 1 closes. The air below the piston passes through Valve 2. As the piston moves upward, Valve 2 closes. Some air from the bladder glass now enters the pump through Valve 1, which opens. The air in the bladder glass becomes thinner. The air above the rubber dam forces the rubber into the bladder glass.

Changes in temperature cause winds. You recall from Problem 1 that the temperature of the surface of the earth and the temperature of the air vary greatly in different places. Let us see what happens when the temperature of the air changes.

Experiment 11: How does the volume of air change when heated and cooled?

Take a test tube and lower it mouth-downward until the open end is just below the surface of water in a glass or pan. Hold or clamp the test tube in this position and then warm the tube with a flame. What happens? After several bubbles of air have come out of the tube, remove the flame and allow the air remaining in the tube to cool. What happens as it cools? Answer the question in the title of this experiment.

Experiment 12: Which is heavier for the same volume, hot air or cold air?

Balance a large open-mouthed bottle or flask on a meter or yard stick, as shown in Figure 45, page 54. When you have the bottle or flask and the weight exactly balanced, bring a flame against the bottle or flask, moving the flame back and forth and around the container to warm it evenly on all sides. This will warm all of the air in the bottle or flask. Note that the end of the meter stick to which the bottle or flask is attached has moved upward. Recall from Experiment 11 that air increases in volume, or *expands*, when heated. Some of the air has been driven out of the container because the air expanded when heated. The weight of the air in the container is less when it is hot than when it was cold. Write an answer to the question of this experiment, and explain why your answer is correct.

From Experiments 11 and 12 you see (*a*) that air expands when heated, and *contracts*, or decreases in volume, when cooled; and (*b*) that cold air is heavier than the same volume of warm or hot air. Similarly, when the air over one region becomes heated, it expands and becomes lighter than the cold air over other parts of the surface of the earth. The cold air, being heavier than an equal volume of warm air, is then pulled downward by gravity, flows along the surface of the earth to the warmer region and under the lighter warm air, and pushes the warm air upward. Or we may say that the pressure of the air in the cooler region is greater than that in the warm region, and the cooler air is, therefore, forced to flow toward and into the warm region, causing a wind.

Air pressure is measured with a barometer. By knowing exactly the pressure at different places, the weather-man can predict not only the direction of the wind, but also the speed. But there must be some way to measure the pressure accurately. In the seventeenth century Galileo first suggested that air exerted pressure, and sought to devise an instrument to measure it. He succeeded fairly well by filling a long tube, closed at one end, with water, and inverting the tube in a tub of water. He found that water remained in the tube to a height of about 33 to 34 feet, held there by the pressure of the air on the water in the tub outside the tube. He also discovered with this clumsy instrument that the air pressure changed, for the water in the tube did not always remain at the same height.

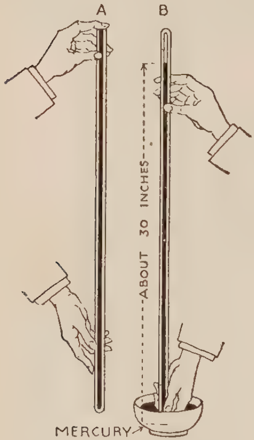


Fig. 48. A Simple Mercury Barometer

"Baros" means pressure and "meter" means measure. This instrument measures weather, that is, one factor of weather, namely, air pressure.

One of Galileo's pupils, Torricelli, became interested in this experiment and decided to use mercury instead of water, so that the tube would not need to be so long. He knew that mercury is 13.6 times as heavy as water and calculated that a tube about three feet long could be used. The instrument which Torricelli made was the first modern *barometer* such as we use today to measure air pressure accurately. You can easily make an instrument like this.

Experiment 13: To make and use a barometer for measuring air pressure.

Heat one end of a glass tube about three feet long in a flame until it melts and closes. When it is cool, fill it with mercury. Place your finger over the open end and invert it in a dish of mercury (Figure 48). Does the mercury completely fill the tube

after your finger is removed? What is left between the mercury and the top of the tube? Measure the height of the mercury in the tube above the level of the mercury in the dish. Allow it to stand, and measure the height of the mercury column from day to day. Explain why this height changes.

Exercise 14. Record your observations in a table like that below.

AIR PRESSURE AND SKY CONDITIONS

DATE	MERCURY HEIGHT IN INCHES	FAIR, CLOUDY, OR RAINY DAY	
10–20–25	28.5	Rainy	

Is there any relation between the height of the mercury and the kind of weather?

Exercise 15. Why must the space above the mercury in the barometer be a *vacuum*, that is, a space without anything in it?

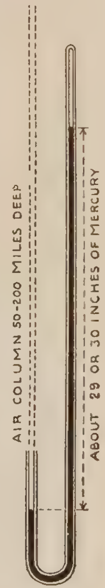


Fig. 49. A Crooked-tube Barometer

Barometers measure the air pressure in inches of mercury. The air pressure on the mercury in the dish holds the mercury up in the tube. It acts just like a balance. As the air pressure becomes less, the mercury falls until it just balances the air, and as the air pressure increases, the mercury is forced up until it again balances the air. If you make a barometer like that shown in Figure 49, you see that it will work like the simple mercury barometer. From this figure you can see that the air column which is above the open arm of the tube and which extends upward to the top of the air covering of the earth, weighs just as much as the mercury in the closed end of the tube.

Exercise 16. If the air pressure in a certain region is 30.2 inches and the air pressure in another region near by is 30 inches, which way will the wind blow at a place between these two regions? Make a drawing to illustrate this, and explain your drawing.

PROBLEM 5: WHY DO WEATHER CHANGES USUALLY COME FROM THE WEST IN MANY PARTS OF THE UNITED STATES?

The prevailing westerlies bring fair and stormy weather. The United States is in the belt of *prevailing westerlies.* This is one of the general belts of winds which are always present on the surface of the earth. These westerlies, made up of large areas of calm weather and areas of stormy weather from 500 to 1000 miles in diameter, move eastward across the country. The area of calm, or *high pressure,* so called because the barometer rises as it approaches, usually brings fair and

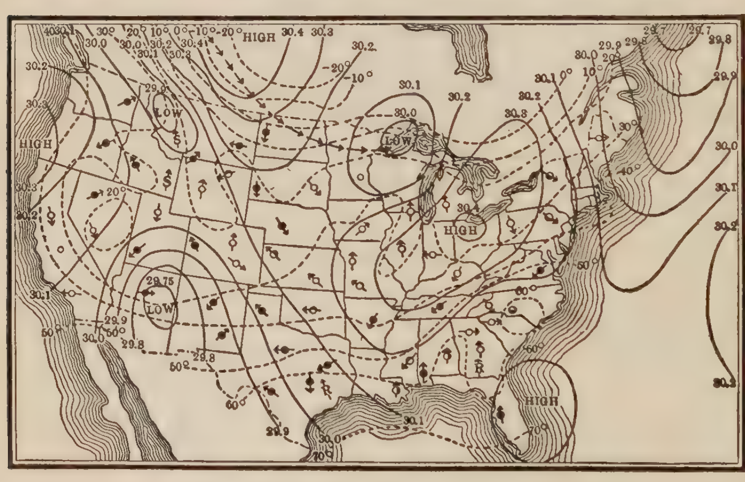


Fig. 50. A Daily Weather Map

The symbols, lines, and words on the map have these meanings: HIGH—center of high pressure; LOW—center of low pressure.

Isobars (solid curved lines) pass through places of equal pressure.

Isotherms (broken curved lines) pass through places of equal temperature. (*Isotherm* means same temperature.)

Arrows fly with the wind; numbers, such as 40°, show temperature on isotherm; numbers, such as 29.8, show pressure in inches on isobar.

Circles. ○ clear, ◑ partly cloudy, ● cloudy, rain, snow.

cooler weather. The area of storm, or *low pressure,* brings stormy weather, and is indicated by a falling barometer. Figure 50 shows a weather map with high and low areas.

Exercise 17. Examine Figure 50. Name the states in which the centers of high pressure and low pressure are located.

In the "high" the air moves downward and outward from the center. It becomes warmed as it approaches the earth, and can hold more moisture. There is little rain, therefore, in the "high" area. The air which moves outward does not go directly outward, but takes a spiral direction because of the rotation of the earth (Figure 51).

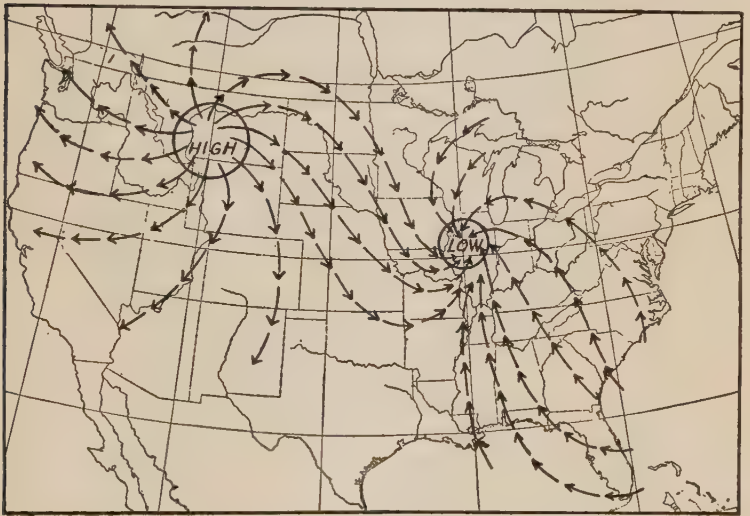


Fig. 51. Winds in and between "Highs" and "Lows"

Direction of wind depends on pressure and rotation of the earth. The figure represents an ideal condition. Local changes in temperature seldom allow the winds to be as regular as they are here shown. The centers of the High and Low are shown in circles. The actual areas are, of course, much larger than the circles.

The "low" area is the region of stormy weather, that is, cloudiness, rain, snow, or thunderstorms. The air at the center of the "low" rises, and the air around the center moves inward with a spiral motion, as shown in Figure 51. This spiral motion, caused by the rotation of the earth, is exactly opposite

that in the "high." As the air in the southern half of the "low" moves northward, it becomes cooled. Clouds and rain often result. (See page 48.) This is particularly true of the southeastern quarter of the "low." Here most rains occur and thunderstorms are frequent in the summer season.

Exercise 18. What changes in temperature, air pressure, and sky conditions take place when (1) a "high" approaches, (2) a "high" passes, (3) a "low" approaches, (4) a "low" passes? Explain.

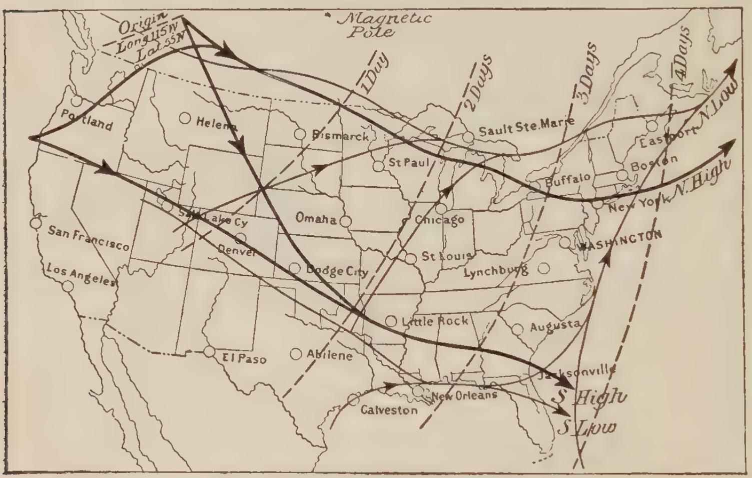


Fig. 52. The Paths of "Highs" and "Lows"

The heavy lines show the usual course of the centers of the "highs"; the lighter lines indicate the paths of the "lows." The average speed of the areas is shown by the broken lines marked 1 day, 2 days, etc.

Exercise 19. Examine Figure 54. Place tissue or tracing paper over it. Trace the words HIGH and LOW in central and eastern United States, and the arrows around these centers. Compare your tracing with Figure 51. Is the general direction of the wind in and around the "high" and "low" the same in the two figures?

The general direction and speed of the movement of the "highs" and "lows" in the United States are shown in Figure 52. They do not always take these exact courses, however,

Fig. 53. Weather Map for a Day Later than Figure 50

Observe the direction in which the "low" has moved since the previous day. This direction is shown by the heavy arrows. Has the "low" moved along the usual path shown in Figure 52?

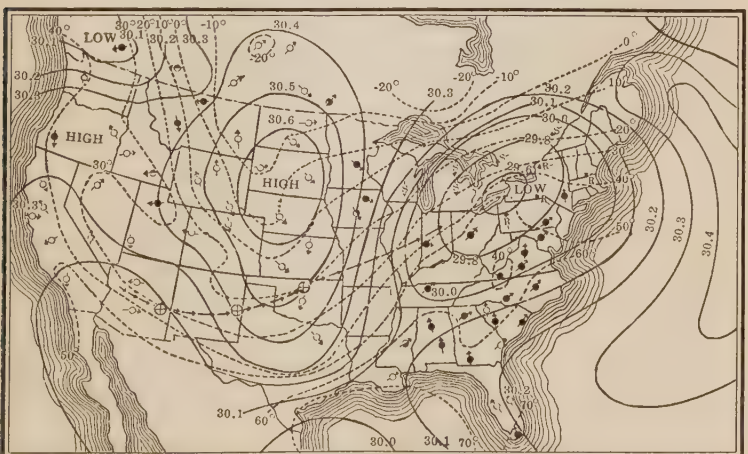


Fig. 54. Weather Map for a Day Later than Figure 53

Note the movement of the "low" since the previous day.

or travel at the speed shown. Many conditions of unequal heating and local winds interfere with the general movement. If it were not for these interferences, it would be easy to predict the changes in weather.

Prediction of weather requires accurate information. In order to predict weather the forecaster must have accurate reports of all weather conditions in different sections of the country. Every morning at eight o'clock over 2000 weather stations scattered throughout the United States, the West Indies, and Canada, telegraph the weather conditions tc the Weather Bureau at Washington. These reports give the air pressure, the direction and speed of the wind, the temperature, the amount of rain or snow, the sky conditions, and the highest and lowest temperatures since the report of the day before. These facts are then charted on blank weather maps. Three of the completed maps are shown in Figures 50, 53, and 54. These maps also show the direction and speed of the movement of the "low" across the country.

Exercise 20. Consult the key to the maps, given in Figure 50, and state the kind of weather which existed in your region on the day for which Figure 50 shows the weather in the United States. Include: (1) condition of sky, (2) direction of wind, (3) barometric pressure, (4) temperature.

Exercise 21. The United States Weather Bureau gives the following statements as aids in predicting weather:

(*a*) When the wind sets in from points between south and southeast and the barometer falls steadily, a storm is approaching from the west or northwest, and its center will pass near or north of the observer within 12 or 24 hours, with the wind shifting by way of southwest and west.

(*b*) When the wind sets in from points between east and northeast and the barometer falls steadily, a storm is approaching from the south or southwest, and its center will pass near to the south or east of the observer within 12 or 24 hours, with wind shifting to northwest by way of north.

(*c*) The rapidity of the storm's approach and its intensity will be indicated by the rate and the amount of the fall in the barometer.

Explain the reasons for the facts mentioned in each statement.

PROBLEM 6: OF WHAT VALUE IS A KNOWLEDGE OF WEATHER AND CLIMATE?

Weather forecasts are of great value. The United States Weather Bureau expends approximately two million dollars every year in collecting information concerning weather and climate, and in sending weather warnings and forecasts throughout the country. The forecasts and warnings are of great value

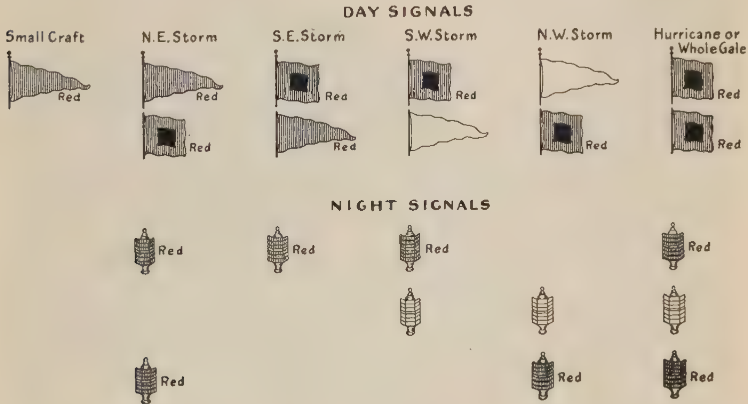


Fig. 55. Weather Signals

Flags during the day and lanterns at night show shipmen what weather to expect. The red flag marked Small Craft in the figure is a warning to small boats and ships that the storm which is approaching may be dangerous. The meaning of the other signals, which are used for large ships, is indicated. Thus a red flag with a black center above a white flag indicates the approach of a storm from the southwest. Similarly, at night a white lantern above a red lantern warns of a storm from the northwest.

to all of us. Shipping interests are protected, our crops are made safer, property and lives along rivers are saved, foods like fruit and vegetables are kept from damage while they are being shipped, and even in cities the lives of the people are made more comfortable and healthful and property is kept safe through the use of these forecasts.

Ships in port are warned against approaching storms. If at sea, they can prepare for the coming storm. To warn ships,

storm signals (Figure 55) are displayed at over 300 stations along the coasts of the Atlantic, the Pacific, the Gulf of Mexico, and the Great Lakes. Warnings of hurricanes are of special value.

The farmer depends upon these forecasts to a great extent. Frost warnings in fruit districts allow him to provide against

Courtesy California Fruit Growers' Exchange

Fig. 56. Orchard or Grove Heaters

The heaters had been lighted just an hour before the photograph was taken. The owner had received a weather forecast which predicted frost during the night. The orange grove was thus protected from freezing.

the danger by using heaters in his orchards (Figure 56). Without such warning, cold waves might freeze the buds, blossoms, or fruit and destroy the entire crop. Grapes may be picked early if a frost is predicted. Raisins may be protected against rain. It is estimated that one frost warning alone saved fruit growers of Florida over $100,000 in a single night. In the summer the forecasts of extremely hot waves are helpful in forest regions where foresters take great care to avoid fires.

Along rivers many thousands of dollars' worth of property

are saved by the flood warnings of the Weather Bureau. A heavy rain at the headwaters of a river may cause a flood farther down stream. With proper warning, cities may protect the banks against overflowing, and prevent great damage such as occurred in Ohio cities a few years ago. Cattle which are being pastured on river-bottom land can be driven to safety on higher land. People may move out of low sections near the river.

The railroads and ships are very dependent upon the Weather Bureau in the shipment of food products which may be frozen by sudden cold waves or spoiled by hot weather. Fruit, vegetables, oysters, fish, eggs, soft drinks, and many other food-stuffs must be properly protected during shipment. The weather forecasts predict what temperatures are to be expected during the next few days, and perishable goods can be protected by proper covering against the cold wave or by proper refrigeration against the hot wave. Produce may be hurried to its destination ahead of the change in temperature, or shipment postponed until the weather is more favorable. The same care must be taken in shipping live stock, meat, and many other products.

Even in city life many activities depend upon a knowledge of the coming weather. Our coal supply must be sufficient for a cold spell. Gas companies must know of the approach of a cold wave so they can furnish more gas, while ice companies must know of coming hot waves so they may have a good supply of ice on hand. Automobile radiators must be drained when a cold spell comes or must be filled with an "anti-freeze" liquid. Greenhouses must provide against freezing. Cities must provide additional help for sprinkling streets during a hot wave, or for removing snow from streets after a heavy snowstorm.

In recent years a study of the weather in the layers of the air far above the surface of the earth has been of value to aviation. Flyers must know the conditions of the air through which they travel. The famous flight around the earth in 1924 would never have been possible without a thorough

knowledge of weather conditions. Balloons carrying weather instruments to different altitudes have made such knowledge possible, by helping to locate good air lanes along which the airplanes may travel with the least difficulty and danger.

Exercise 22. If you were asked to take one side of a debate on the question: "Resolved, that the weather forecasts are more valuable to the farmers than to city dwellers," which side would you take? Prepare a five-minute speech for your side.

An important part of the work of the Weather Bureau is the study of climate. Records of weather kept over periods of years furnish the data for determining the climate of a region. For example, if the records show that the average temperature of a region for a long period is low and that the total rainfall is light, such a place has a cold, dry climate. Conversely, a region with heavy rainfall and a high average temperature has a hot, wet climate. You must, of course, bear in mind that in the temperate zone the seasons cause great changes in temperature and humidity.

The value of a knowledge of climate may be seen from the following statement taken from the pamphlet *The Weather Bureau*, published by the Government Printing Office:

The miscellaneous climatological data are used in medical and scientific studies of the relation of weather to diseases and other conditions of health, life, or human pursuits; by railroad companies in the adjustment of claims and demurrage charges; by home-seekers; by invalids in search of health resorts; by irrigation investigators; by contractors and builders in settling labor accounts; by merchants in studies of the relation of the weather to their daily sales; by gas and electric light companies in showing their customers the relation of their monthly bills to the varying hours of daylight at different seasons of the year; as adequate testimony in court proceedings; in dry-farming investigations; in life and migration of insect pests; in plans for the development of the arid regions; in the preparation of historical records; by bond and investment companies in determining the loan values of farm lands in newly opened countries; in short, in nearly every calling in which the weather plays any part.

Exercise 23. Which of the uses of climatological data mentioned in the preceding paragraph is the most valuable to you? Explain why you think so.

Review Exercise on Unit II. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit II and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT II

1. Why are the heat belts (Figure 33) so irregular in shape?

2. How will the height of the mercury in a barometer change if the barometer is carried to a high mountain? Into a deep mine?

3. Blow your breath against a windowpane. How do you explain the formation of the film of moisture?

4. Frosts are less likely on cloudy than on clear nights. Why?

5. Why is the surface of the moon which faces the sun extremely hot while the opposite side is extremely cold?

6. What is the total force of the air in tons on a garden 100 feet long and 240 feet wide?

7. Keep a morning and afternoon record of the kinds of clouds in the sky and the kind of weather. After many days see if your records show you any relation between the clouds and the weather which follows the appearance of the different clouds.

8. Why must the air be removed from the space above the mercury if the thermometer is to be marked off in divisions of equal size?

9. Why does a south wind often bring rain, while a north wind usually brings fair weather in most parts of the United States?

10. Why do glasses in spectacles become cloudy when a person comes into a warm room from the cold outside?

11. Why does the "steam" from the mouth of a teakettle disappear?

12. How do you explain the disappearance of clouds in the sky?

13. The sun is not so warm early in the morning or late in the afternoon as it is at noon. Explain.

UNIT III

PROVIDING A GOOD FOOD SUPPLY

Preliminary Exercises

1. List the different foods you had for dinner yesterday. Opposite each indicate the plant or animal from which the food came.

2. Name the different methods which you use at home to keep your food pure, so that it will not "spoil" and make you sick.

3. People are often advised by doctors to eat such foods as fruits, vegetables, and bran bread. Why?

4. How does canning keep foods from spoiling?

5. Make a list of the foods you ate yesterday. Opposite each tell whether it was a raw food or a prepared food. If it was a prepared food, state how it was prepared, using such words as fried, boiled, preserved, manufactured, etc.

6. Name plants and animals most commonly used for food in your community. Make a table like that in Exercise 3, page 35.

PLANTS	ANIMALS
1. Wheat	1. Hog
2. Corn	2. Chicken
3. Peach	3. Fish
etc.	etc.

7. For what different purposes do you eat?

8. Why do you eat different kinds of food?

9. There are many ways of preserving food. List them.

10. How does climate determine the kind of plants you eat? The kind of animals?

11. In what ways does our food supply depend upon the sun? The movements of the earth? The weather?

12. Make a table showing ten manufactured foods, the source of each, and how each is prepared.

FOOD	SOURCE	PREPARATION
Butter, etc.	Cow	Churning cream and salting

THE STORY OF UNIT III

Before man had learned to understand and use the forces and materials of nature, his food supply depended almost entirely upon the climate of the region in which he lived. He made his home where nature provided enough food to support life. Most of his time was spent in search of something to eat. The stream, lake, ocean, field, and forest furnished him with such food as he could obtain by fishing and hunting. Fish, animals, berries, leaves, stems, roots, and seeds made up his daily menu. He learned what was good to eat by sampling nature's products. As the food in his neighborhood became exhausted, he moved on to other places. Each day he struggled with nature against starvation.

Underwood and Underwood

Fig. 57. Cooking over an Open Fire

These African natives are broiling goat flesh. Perhaps on picnics or camping trips you have prepared foods in this way.

When he had discovered the use of fire, he began to cook certain foods. This, he found, improved their flavor. For a long time he was satisfied to roast his food over an open fire (Figure 57), or in the hot ashes. When he learned how to use fire in making fireproof vessels of clay, he found another method of preparing his food: he was able to stew and boil his foods in water (Figure 58). Perhaps he also found that cooked foods did not spoil so quickly as raw foods, and thus he was able to keep them longer without spoiling.

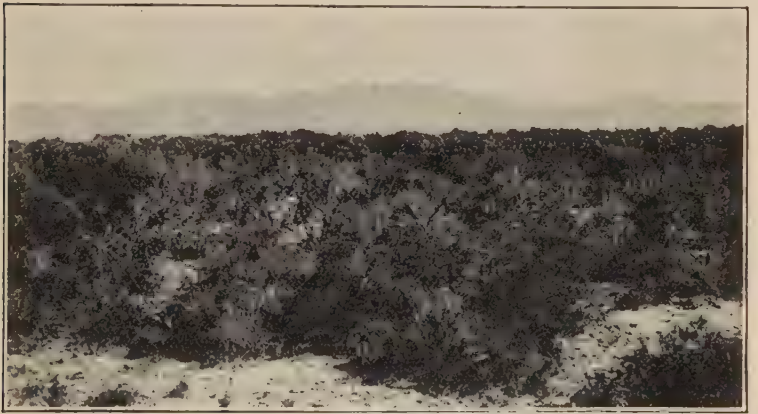
One of the important early steps in man's struggle with nature in certain climates took place when he began to tame wild animals and keep them as a source of food for the long winter months. The animals produced their young and furnished him with a constant supply of animal food. At the same time he found it necessary to secure plant food for the animals. This was possible, because by this time he had learned to cultivate the soil and grow certain grain-producing plants. He was now a man of property; he began to build a more or less permanent home and to live in communities.

Fig. 58. Stewing Food in a Pot of Water
Stoves are still unknown in many places.

With the growth of population in the community and with the establishment of other communities came the need for better methods of farming and of exchanging goods. New varieties of crops and new animals were raised. An increasing number of devices to aid in the cultivation of the soil and to increase the comforts of home were manufactured. The farmer sent his food products to the city, where they were sold or stored for future use, and the city dwellers exchanged manufactured goods for them. Thus, gradually, there grew up our present civilization, in which each community and each man takes part in producing, manufacturing, and exchanging the foods which are essential to our daily life. We see that this great development took place as a result of man's discoveries in his struggle with nature.

In his study of nature man found that his food supply was dependent not only upon the climate but also upon the kind of soil. The climate could not be changed; so he directed his

efforts toward cultivating and improving the land. By cultivating the soil in various ways he was able to raise many new food-producing plants. By irrigating (Figures 59 and 60),



Courtesy United States Reclamation Bureau

Fig. 59. A Region Before Irrigation

Before irrigation this region in Idaho was useless to man. It was covered with cactus and sage brush and would support no food-producing plants.

Courtesy United States Reclamation Bureau

Fig. 60. The Same Region After Irrigation

After irrigation great fields of grain replaced the cactus and sage brush.

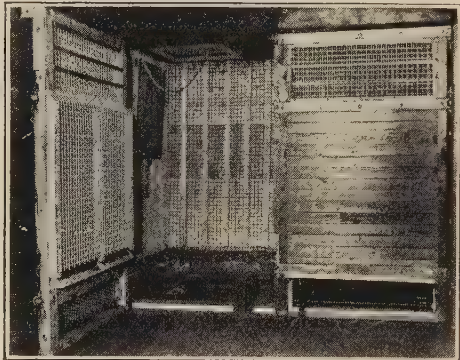
he made it possible to raise usable plants and animals in regions which were until then of little if any value to him. By draining he made huge areas of swamp-land into fertile fields. By experimenting he produced plants and animals better adapted to live in different climates. By fertilizing the soil with materials needed for plant growth, he greatly increased the productivity of the soil. Government and state experiment stations were established to examine the soils, to learn the best methods of cultivation for different crops, to find what crops are best suited to the soil, to determine the kind of fertilizers necessary to keep the soils in good condition, to study methods of irrigating and draining, and to devise ways of protecting crops against injurious insects and such other living enemies as wheat rust, scales on trees, and mildew. With a larger supply of plant food, more animals, such as cattle, hogs, sheep, and chickens, could be raised. Thus our supply of both plant and animal food has been increased by the introduction of modern methods of agriculture.

Along with this knowledge of how to raise plants and animals has come an increased knowledge of the kinds of food which the human body needs. It has been found that a proper food supply must furnish several kinds of materials to the body.

Proteins, contained in such foods as peas, beans, eggs, and lean meat, are required to build and repair the body. *Carbohydrates*, which include starch and sugar, and which are present in many vegetables and in grains, must be eaten in order to supply the energy which keeps us warm and enables us to move. *Fats*, found in vegetable oils, butter, milk, and meats, are also needed for furnishing energy and may be stored in the body for future use. *Minerals* are important as builders of bone and other parts of the body, such as the blood. *Water* is also an essential, and is obtained in foods as well as in its natural form. Recent investigations have also shown that certain foods, such as butter, beef, eggs, milk, and apples, contain materials called *vitamines*, which are necessary for

body health. A knowledge of the uses of these various food substances and of the correct proportion of each in our daily menu is necessary to everyone who wishes to provide his body with the kind and with the amount of food which will keep it in a healthy condition.

Man has made still another important discovery in connection with his food supply. He has learned why foods spoil and how to prevent them from spoiling. This is of great importance to all of us today, since foods must be shipped long distances and must be kept for long periods of time before they are used. Having learned that decay is caused by small *organisms*, that is, small plants and animals which get into the food, man found that he can keep them from spoiling the food. Their growth may be prevented, or they may be killed. Organisms are killed by high temperatures; at very low temperatures they cannot grow and produce poisons. Thus, drying foods or keeping them cool in refrigerators prevents the growth of these small organisms, so that the food remains in good condition (Figure 61). Similarly, cooking, heating, and treating foods with certain chemicals kill the organisms. These and other methods of preservation not only make it possible for us to keep foods for long periods, but they also prevent the entrance into our bodies of disease-producing germs which may be present in spoiled food.



Courtesy American Railway Express

Fig. 61. Ice Chamber of a Refrigerator Car

The left of the two doors is open, showing the chamber in which the ice is to be packed. The ice is loaded through the trap-door in the roof. The remainder of the space in the car will be filled with perishable foods.

PROBLEM 1: WHAT ARE THE SOURCES OF OUR FOOD?

The water and the soil are the homes of the plants and animals we eat. Here, under proper conditions of climate, they grow and manufacture our food materials. If you examine

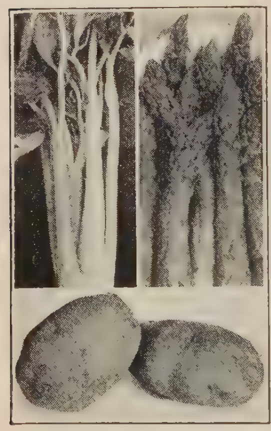


Fig. 62. Stems as Food

Fig. 63. Roots as Food

the list you made in Preliminary Exercise 6, as well as other sources which you might add, you find that the principal plant foods are fruits, vegetables, and grains from the garden or field. Similarly, you see that the important animal foods are obtained from cattle, hogs, sheep, fowls, and fish. If you live in the country, many of your foods are obtained directly from the farm. But if you live in the city, most of the foods on your table have passed through many hands. Originally they came from the water and the field or garden, but they have passed through the hands of the fisherman or farmer, the wholesale house, the commission merchant, broker, packing

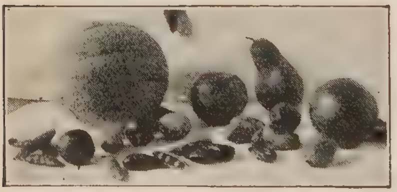


Fig. 64. Fruits and Seeds as Food

house, railroad, and storekeeper before they reached your kitchen and were prepared for the table.

The value of the food products raised and consumed in the United States each year is enormous. In one year the United States exported more than $2,034,000,000 worth of food products. During that same year $1,816,000,000 worth of food products was imported. The annual consumption of meat per capita has been estimated to be about one hundred eighty pounds. When we consider that meat is only a small part of our daily food, we can easily see that each of us eats many times his weight in food each year. When you remember that the population of the United States is more than 110,000,000, you realize the tremendous amount of food which must be produced annually.

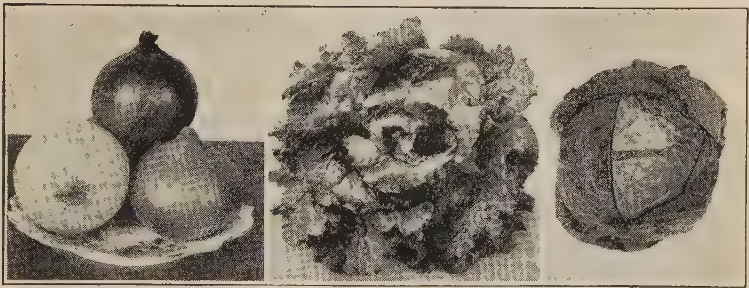


Fig. 65. Leaves as Food

Fig. 66. Buds as Food

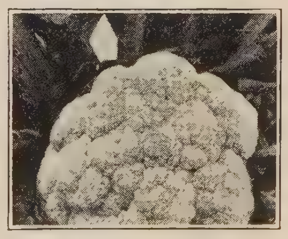


Fig. 67. A Flower as Food

Different parts of the plant are used as food. The principal parts of green plants, which furnish the greater proportion of our food supply, are: root, stem, leaf, bud, flower, seed, and fruit (Figures 62-67). These are used directly or are manu-

factured into various plant products. The bud and the flower are less commonly used than the other parts. In the table below you will find the names of food plants and their products listed under the part of the plant which supplies the food. Those marked (*) are manufactured products.

TABLE II: SOURCES OF COMMON PLANT FOODS

ROOT	STEM	LEAF	BUD	FLOWER	SEED	FRUIT
	celery	chard shoots lambsquarters				
Turnip	Asparagus	Cabbage	Brussels Sprouts	Cauliflower	Wheat	Tomato
Radish	Potato	Lettuce	~~[illegible]~~		Rice	Peach
*Beet Sugar	*Cane Sugar	Onion	asparagus		*Cornstarch	Banana
eggplant	pie plant Beet	spinach parsley celery	Rose			beans peas

Many plant products appear on the table every day. Suppose, for example, that your meals for yesterday were as follows:

BREAKFAST	NOONDAY MEAL	EVENING MEAL
Orange, or baked apple	Pea soup	Roast beef
Oatmeal, cream, and sugar	Creamed asparagus on toast	Mashed potatoes
Eggs and bacon	Lettuce and tomato salad	String beans
Toast	Hot rolls	Bread and butter
Butter	Butter	Grape jelly
		Chocolate cake

Look over the menus and check with a light pencil mark the plant products.

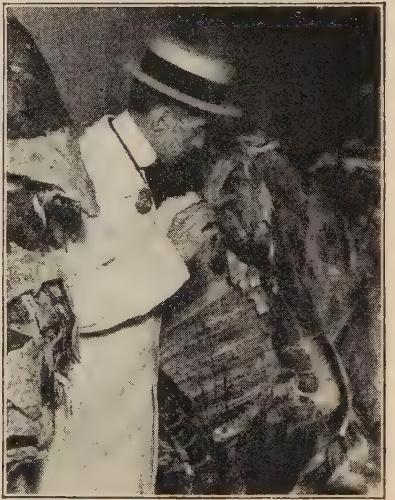
Exercise 1. Copy Table II and add 20 other plants or their products, placing each in the proper column.

Exercise 2. List the plant foods given in the menus above, and after each, name the plant and the part of the plant from which it came.

Animals furnish us with much food. Cattle, hogs, and sheep furnish us with our principal animal foods. As in the case

108

of the plants, various parts of these animals are used. The most commonly eaten parts are the flesh, heart, liver, pancreas, and brains. Often in the country these animals are killed and the meat used as needed, being kept from spoiling by refrigeration, smoking, or salting. In the small town the animals are slaughtered by the meat-market man from day to day and kept in the refrigerator, so that fresh meats may be supplied to the customers. A large proportion of the animals is shipped to great meat-packing centers like Chicago, Omaha, Kansas City, New York City, Cincinnati, and Los Angeles. Here they are slaughtered and prepared for meat after they have been inspected and the diseased animals rejected (Figure 68). The fresh meats, such as beef, veal, pork, lamb, and mutton, are again examined in the packing house by inspectors of the United States Department of Agriculture. The meats that pass inspection are then placed in cold storage; or they may be immediately distributed in the city, shipped in refrigerator cars to other markets, preserved by smoking, drying, or "curing," or made into many kinds of canned meat products.



Keystone View Co.

Fig. 68. Government Inspector Examining Meat

All meat must be examined and stamped by government inspectors before it can be sold. In this way the government protects you from many diseases.

To a lesser extent fish, chickens, ducks, geese, and turkeys furnish us with food materials. The fishing industries have become very important. Poultry farms are very common,

and it is estimated that the value of poultry products is equal to that of our wheat crops. Because the supply of the animals mentioned in this paragraph is more or less limited or because the cost of raising and shipping them is great, they are usually more expensive than the other meat foods previously discussed.

Few meals would be complete without one or more animal products such as cream, milk, butter, cheese, and eggs. They have a very high food value and are therefore economical foods. Tremendous quantities of them are produced and used each year. For example, the total production of eggs in the United States for one year would build a wall of eggs thirty feet high and one egg thick from New York to San Francisco. New York State alone supplies enough milk in a single year to fill a lake one mile long, a quarter of a mile wide, and ten feet deep.

Exercise 3. Make a list of the kinds of meat which you eat. After each, state the animal from which it comes and the part of the animal used. Inquire at home and at the meat market to make your list as large as possible. If you can do so, obtain from your local meat market charts which show the various cuts of meat obtained from different animals. Use the following form to arrange your data.

Kinds of Animal Foods and Their Source

FOOD	ANIMAL	PART OF ANIMAL
Ham etc.	Hog	Hind-quarter

All foods come from plants. Although both plants and animals are used as sources of our food supply, the green plants are really the food factories of the world. They take from the soil, water, and air the materials of which our food is composed. Water and minerals enter the plant through the roots and are transported through the stem to the plant leaves (Figure 69). Air containing *oxygen* and *carbon dioxide* enters the leaves through thousands of tiny openings (*stomates*) in

the leaf covering (Figure 70). Scattered through the leaf are many small masses of *chlorophyll*, which has the property of using the light energy from the sun in such a way that the water and carbon-dioxide gas are changed to carbohydrates. During this process, oxygen is given off through the stomates. Since burning, decaying, and breathing take oxygen out of the air, this action of leaves in giving off oxygen is very important in that it keeps the necessary supply of oxygen in the air. Plants manufacture not only carbohydrates but also proteins and fats.

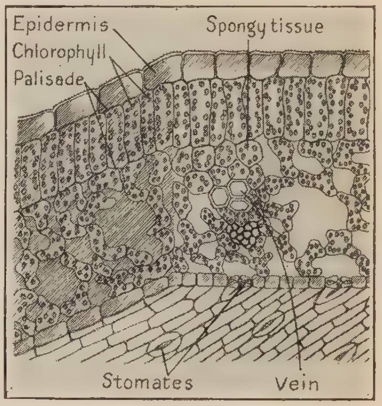


Fig. 70. The World's Greatest Factory—the Leaf

This is what a cross-section of a leaf looks like when placed under a high-powered microscope. The epidermis and palisade layers prevent the leaf from drying up. The small round dots scattered through the leaf are small bodies containing chlorophyll, which gives the leaf a green color.

Experiment 14: How can we show that leaves manufacture starch?

(*a*) Place a very small piece of starch in a test tube one-fourth full of water. Heat the mixture to boiling, and then allow it to cool. Add three or four drops of iodine solution. Note that the solution turns blue. This is the test for starch.

(*b*) Secure leaves from some nasturtium, bean, or other plants which have stood in the direct sunlight for several hours. Place them in hot water for several minutes, and then boil them in alcohol until the green coloring (chlorophyll) is dissolved. Place the leaf on a glass plate and add several drops of iodine solution. Hold the leaf up to the light. Is starch present?

The newly manufactured materials in the plant are carried to all its parts by the sap which circulates through the plant in much the same way as the blood circulates in your body.

Experiment 15: How does the sap travel through a plant?

Obtain several living shoots of such plants as corn, lily, parsnip. Place the cut ends in a solution of eosin or red ink. Allow them to stand for twenty-four hours and then cut across the stem at various points and observe the freshly cut cross-section. Also observe the leaves. Does the sap travel through definite channels?

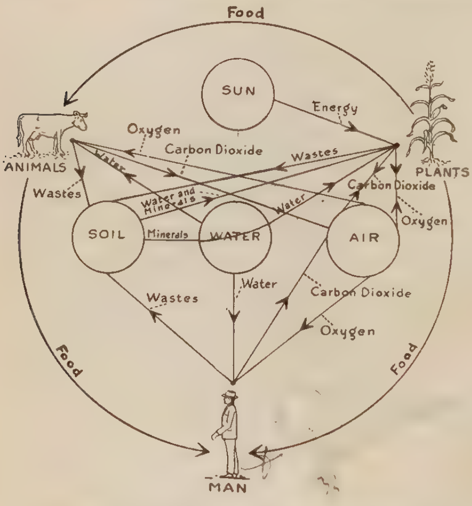


Fig. 71. The Food Cycle in Nature

This circulation of sap makes it possible for every part of the plant to grow. Some of the materials which are not immediately used for growth are stored in the various parts of the plant. Certain of these stored materials furnish the food for animals and man; others are used by the plant in growing. Since animals cannot combine the raw products from the soil and air as the green plants do, they must eat plants and change them into new animal materials. Thus all of our food supply comes directly or indirectly from plants. It is also interesting to note that when the plants and animals die and decay, the materials of which they are composed become a part of the soil and air and furnish raw products for other growing plants.

Exercise 4. Examine Figure 71, which shows how plants, animals, and man depend upon each other and upon the soil, water, and air. Under the title "Facts from Figure 71," state as many facts as you find represented in the diagram. Thus:

(*a*) Plants furnish food to animals. (*b*) Plants furnish food to man. (*c*) Plants give oxygen to the air, etc.

PROBLEM 2: WHY DO YOU EAT FOOD?

The body is a complex machine. Two common answers to the question of Problem 2 are: (1) "to keep alive," (2) "to satisfy hunger." Neither of these answers explains how the body uses food. To give a more scientific answer you must consider what becomes of the food which is taken into the body. You must think of the body as a complicated machine which requires some force or energy to keep it in running order and some materials to make it grow and keep in repair.

The body may be compared with a steam engine by showing the similarities and differences between the two. Both require energy to make them move; both work best at a certain temperature; both must be kept in repair. On the other hand, the body can grow and repair itself, two qualities which the engine does not have. Also, the body generates its own power within itself, while the engine must be supplied with energy, in the form of steam, from a boiler outside the engine. Moreover, the body is composed of millions of parts made of many different materials, whereas the engine has relatively few parts, which are made almost entirely of iron and steel.

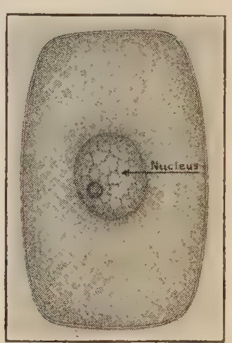


Fig. 72. A Typical Cell

Your body is made of countless millions of cells. They are composed of *protoplasm*, which is the living material in all living things. In the center is a somewhat denser protoplasm, the nucleus. If this is destroyed, the cell dies.

The body grows. One of the most striking qualities of a living thing, like the human body, is its power to grow. Year after year during the earlier part of one's life the body becomes larger. This growth comes about through the increase in the very great number of minute *cells* of which the human machine is composed. Figure 72 shows the structure of a typical cell. The cells which make up the various parts of the body are of many different kinds.

The plant and animal foods which you eat contain the materials which the body uses to manufacture the necessary cells. As you grow, new cells of all kinds are produced by the division of the old cells (Figure 73), and each part of the body increases in size. Of course, you must eat the proper variety of foods to supply the needed materials. If you do, the body changes these foods into the required human materials, and you gradually become a full-grown, healthy individual.

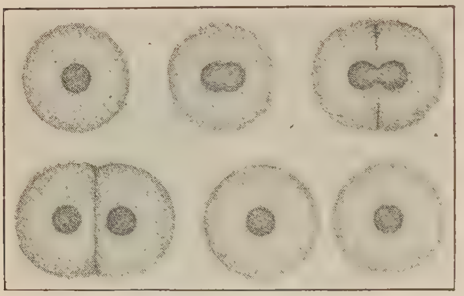


Fig. 73. Stages in Cell Division

The single cell in the upper left hand corner slowly changes, becoming two separate cells, each like the parent cell. The nucleus divides, forming two nuclei, one for each cell.

The body requires heat. Have you ever tried to start an automobile engine on a cold day? And do you recall how the engine "sputters" and "coughs" until it is thoroughly warm? Perhaps you have also noticed that the engine does not run so well when it becomes too hot. Your body is much like the engine. It operates best at a certain temperature. Unlike the engine, however, the human body is always at the same temperature if you are in good health. Very warm or very cold air does not change the temperature of the body as it does in the case of the engine. The body usually remains at 98.6° F., its normal working temperature. It is only in case of sickness that it may drop much below this point and have a sub-normal temperature, or that it may rise considerably above 98.6° F. and produce a *fever*.

The heat which keeps the body warm is furnished by the food which you eat and the oxygen you breathe. In the engine the heat required to change the water into steam is produced by the *combination* of the oxygen gas in the air with the

fuel. In the body, oxygen is taken into the lungs when you breathe. This oxygen passes through the thin walls of the tiny blood vessels in the lungs and gets into the blood (Figure 74). The blood is then sent back to the heart, which pumps it through the rest of the body. The food you eat is also taken into the blood and transported through the body. As the blood circulates, it is constantly giving up food materials and oxygen to cells that need them. The food may be manufactured into new cells or used to repair old cells, or it may be stored for future use.

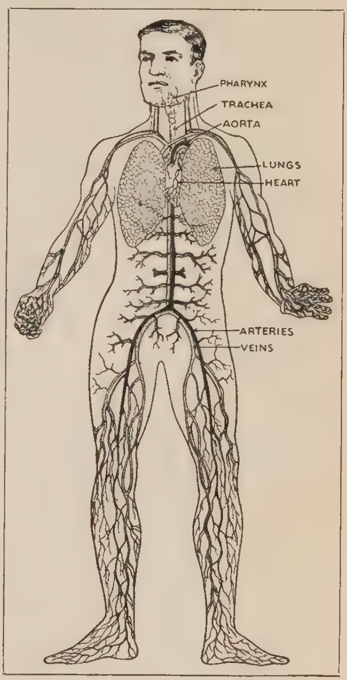


Fig. 74. How Oxygen is Carried to All Parts of the Body

The arteries carry blood away from the heart, and the veins bring blood back to the heart. Figure 74 shows how the blood vessels subdivide so that all parts of the body may be reached.

The different cells and food materials stored by the body are "burned" by the oxygen, producing heat. This type of "burning" is so slow that no flame is present as in the case of coal or wood. It is called *slow oxidation.* The heat given off by the oxidation of the cells and food materials keeps the body warm. Producing heat to keep the temperature of the body uniform is, therefore, another use of food.

Food furnishes energy for bodily activities. Some part of the body is always in action, even when you sleep. During your waking hours you are active doing such things as thinking, walking, writing, breathing, jumping, playing, eating, and seeing. In your sleep you breathe, your heart

continues to pump blood, and various other activities are going on inside your body. Every one of these activities requires some force or energy to produce it. This energy is supplied by the slow oxidation which is constantly taking place in the cells. The proper energy-producing food materials must therefore be present in every active part of the body.

How this energy is produced will, perhaps, be clearer by further comparing the body with the engine. In order to make the engine move, steam is needed. The energy of the steam comes from the heat produced by burning coal. The heat energy is first changed to the energy, or force, of steam. This, in turn, drives the engine and gives it energy of motion, which may be used to pull a train, saw wood, or run a dynamo. Similarly, in the body the energy produced by oxidation of the cell materials may be used to move any number of the more than five hundred different muscles, to send nerve messages throughout the body, or to think. There are, however, two important differences here between the engine and the body. The fuel is outside the engine, while the body uses fuel within itself; also, the fuel for the engine is not made of the same material as the engine, but the fuel of the body is part of the body itself. There is, then, a third reason why you eat, namely, to produce the energy which makes the activities of life possible.

The body must be kept in repair. When a steam engine is used, its parts become worn or broken. These must be repaired or replaced by new parts. Likewise the cells which make up the body are constantly being worn out. Every time you wink your eye, sit down, get up, think, look, listen, or move any part of the body, certain cells are destroyed. These must be replaced. Food materials are required to rebuild the worn parts. The human machine changes the food into living material and repairs the damage done. This wonderful power of repair in the human body is shown strikingly in the case of broken bones or serious cuts. With the

broken ends of bones or the cut parts held together by bandages, new cells grow (Figure 73, page 84,) and in a short time the damage is repaired.

You may summarize the answer to Problem 2, then, by giving four reasons for eating food: (1) to furnish material for growth, (2) to supply the heat which maintains the temperature of the body, (3) to produce the energy required by various activities, and (4) to keep the body in repair. Perhaps one other use of food might be mentioned, namely, storage for future use. When more food than is necessary for the four purposes given is taken into the body, some of it may be stored.

Exercise 5. Explain why people eat more in winter than in summer.

Exercise 6. Bears find a convenient hole to rest in during the winter and eat no food during that time. How do they keep alive?

Exercise 7. Why does hard work or strenuous exercise increase your hunger? Why do you breathe more rapidly during such work or exercise?

PROBLEM 3: WHAT KINDS OF FOOD SHOULD YOU EAT?

You have seen that food not only satisfies your appetite, but that it serves four important purposes in the body. In order to serve these purposes several kinds of food materials are essential. It therefore becomes necessary for the chemist to analyze the different kinds of foods, that is, to determine what food materials they contain, so that people may be able to select a proper diet.

Experiment 16: How can the presence of starch, sugar, protein, fat, and minerals in foods be shown?

1. Starch

(*a*) Cut a thin slice of potato. Place it in water and scrape it with a knife. Remove the potato slice and boil the scrapings in the water. Test for starch with iodine solution. (Tincture of iodine, which can be obtained at a drug store, may be used.) Result? Add only a few drops of the iodine.

(*b*) Other materials, such as beans, peas, oatmeal, rice, crackers, and bread, can also be tested for starch. Make a paste of the material by grinding it in a little cold water. Then add hot water, mix thoroughly, and allow to cool. Test the mixture with iodine. Record whether or not starch is present.

2. Sugar

(*a*) Grind some raisins and add a little water. Allow the solid materials to settle, and then pour off the liquid into a test tube. Add about one cubic centimeter (1 c. c.) of Fehling's solution to the liquid, and boil. A yellow-red color shows the presence of grape sugar. (Fehling's solution may be obtained at any drug store.)

(*b*) Test other foods as directed in (*a*), and record your results.

3. Protein

(*a*) Place a small portion of the white of an egg in a test tube and add a little water. Then add 5 c. c. of nitric acid and heat gradually to boiling. Allow the solution to cool, pour off the acid, and add 10 c. c. of ammonium hydroxide. A deep orange color shows the presence of protein.

(*b*) Test other materials, such as meat, flour, and bread, and record your results.

4. Fat

(*a*) Rub a small piece of lard or butter on a sheet of glazed paper. Hold the paper over a flame until the butter melts, and then hold the paper up to the light. The spot made by the butter becomes *translucent;* that is, it allows light to pass through the paper.

(*b*) Test peanuts for fat by crushing them in a mortar and then rubbing the powder on thin paper.

(*c*) Test other materials for fat. (Unless fat is present in large quantities, it is very difficult to detect it by these methods.)

5. Minerals

(*a*) Obtain a small piece of bread and heat it at a high temperature until all of the materials which will burn have disappeared. The remaining material, ashes, is composed of minerals.

(*b*) Heat a beaker or dish of water until the water is completely evaporated. Note the white solid material left on the sides of the beaker. These are minerals which remained in the beaker after the water had evaporated.

(*c*) Test other food materials for minerals as directed in (*a*).

Exercise 8. Go over all the results obtained in Experiment 16 and rewrite them in a table as follows:

TESTS FOR COMMON FOODS

FOOD	STARCH	SUGAR	PROTEIN	FAT
Potato	+			

Place a + sign in the proper column to the right of the food if your tests show that starch, sugar, protein, or fat is present. If the test does not show the presence of starch, sugar, protein, or fat, place a − sign in the proper column.

Proper diet depends upon climate. The climate of a region not only governs the kinds of food which are available, but it also determines the kind of food man should eat. In the frigid Arctic regions, for example, the supply consists largely of animal foods, for few plants grow in very cold climates. Moreover, the temperature of the air is much lower than that of the body, and the body loses a great deal of heat. This makes it necessary to eat foods which will produce a large amount of heat, and explains why fatty foods are used in great quantity by inhabitants of Arctic regions.

In warm climates, like the tropics, many plant foods are to be had, and the body needs little heat-producing food. Therefore few fatty foods are eaten there. The climate of our own country makes possible an abundant supply of both plants and animals. Since the climate varies with the season of the year, it is necessary to select the proper amount of heat-producing foods during the different seasons. Thus you eat more foods containing carbohydrates and fats in the winter than in the summer. Throughout the year in any climate you need, of course, the other kinds of food for the growth and repair of the human machine.

Proper diet depends upon your activities in life. Have you noticed that you become very hungry after a strenuous game or after several hours of hard physical work? Your appetite is nature's signal that food is needed. The physical exer-

tion tears down the muscle cells and uses up the stored supply of food. More food is needed to repair the cells and to restore the energy of the body. Since, as you recall, proteins are needed to rebuild the cells, your body requires that you select some foods which contain this food material, as well as other kinds of food. Without proteins the torn-down cells cannot be rebuilt.

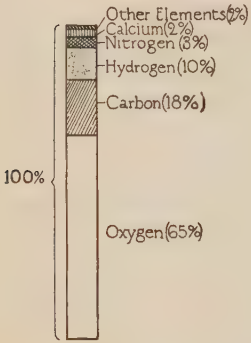


Fig. 75. Percentage of the Important Elements in Protoplasm

These elements are contained in the water you drink and the food you eat.

The living substance in the cells is called protoplasm. It looks much like the white of a raw egg and is composed of several simple substances, or elements. Everything in the world, living and non-living, is composed of these elements, 85 of which are known. They are called *elements* because they have never been separated into simpler substances. The principal ones which are necessary to build *protoplasm* are carbon, hydrogen, oxygen, and nitrogen (Figure 75). Now, proteins are made of the same elements and can furnish the necessary materials to rebuild the cells which are worn out so rapidly by the bodily activities. You see, therefore, that meats, fish, eggs, milk, and other protein foods must be eaten at all times, but that such foods should be consumed in larger quantity when one is engaged in vigorous physical work or in sports that involve strenuous exercise.

There is, however, always the danger of eating too much protein. It is often the case that boys and girls eat so much protein food at one meal that their appetite is satisfied, and they take little of fats and carbohydrates. This is undesirable for several reasons. First, without carbohydrates and fats the protein food must furnish fuel as well as repair materials. This is not economical, because the common protein foods are

usually the more expensive. Second, the protein foods are not so easily digested as the carbohydrates and fats, and produce more harmful waste materials. Such practice, therefore, puts an extra strain on the digestive apparatus of the body. Also, the kidneys and liver must work overtime to free the body from the unnecessarily large amount of wastes.

You should gain the idea from the preceding paragraph that a variety of foods makes up a well-balanced *diet*. There should be enough of each kind of food in the daily menu, or diet, to serve all purposes. This is particularly true in the city, where much of our time is spent in school or in the office, and where the proper amount of physical exercise is not always secured. Such *sedentary*, or physically inactive, life and the present-day condensed or concentrated foods are likely to produce constipation. If the bowels are not kept free from the harmful wastes by daily or more frequent movements, these wastes produce poisonous materials which cause digestive disorders. Thus you need vegetables and fruits and certain minerals, all of which promote the bowel movements and prevent constipation. Many of the vegetable foods, like whole-wheat bread, unpeeled potatoes, peas, and beans, are the most economical sources of protein, and contain the proper proportion of protein and the other food materials.

Proper diet depends upon age, weight, and height. Age is an important factor in selecting food. Young people who are growing rapidly require a larger amount of food in proportion to their weight than older people. The former need to build many new cells in growing, while the latter need only to repair the torn-down cells. Also, younger people are usually more active and therefore require more energy-producing food. Probably you have often been reminded of the fact that you eat more food than do older members of your family. This is reasonable at a certain age. You should not, however, overeat just to satisfy your appetite, for your appetite is not always a safe index of the amount of food which the body

should have. You may leave the table hungry and still have eaten all your body requires.

The amount of food which you require depends also on your size, that is, your height and weight. Table III shows the correct weights of boys and girls of different ages and different heights. Examine the table and compare your weight with that given for your age and height. If your weight is only a few pounds above or below the figure given for your age and height, it is not a serious matter. If, how-

Courtesy American Museum of Natural History

Fig. 76. A Sample Breakfast

Here is a good breakfast for a growing boy or girl. It consists of oatmeal, cocoa, toast and butter, milk, and baked apple.

ever, you are more than 15 pounds underweight, your diet should be improved. On the other hand, considerable overweight means that you are too fat. This should lead you to exercise more, and eat less of those foods which produce fat, such as sugar, fats, and starch. Candy and ice-cream are two such fat-producing foods which you should avoid. By guarding against your appetite and by taking the proper exercise you may do much to reduce your weight and figure to normal. You should have some expert, like the doctor or the home-economics teacher, determine your diet. Some sample meals planned by experts are shown in Figures 76, 77, and 78.

TABLE III: HEIGHT-WEIGHT-AGE TABLE

AGE	11 YRS.		12 YRS.		13 YRS.		14 YRS.		15 YRS.		16 YRS.	
HEIGHT	B*	G*	B	G	B	G	B	G	B	G	B	G
48	57	56										
49	59	58										
50	61	60	62	61								
51	64	63	65	64								
52	67	66	68	67								
53	69	68	70	69	71	70						
54	72	71	73	72	74	73						
55	75	74	76	75	77	76	78	77				
56	79	78	80	79	81	80	82	81				
57	82	82	83	83	84	84	85	85	86	86		
58	85	86	86	87	87	88	88	89	90	90	91	91
59	88	90	89	91	90	93	92	94	94	95	96	96
60	92	94	93	95	94	97	97	99	99	100	101	102
61	95	99	97	101	99	102	102	104	104	106	106	108
62	100	104	102	106	104	107	106	109	109	111	111	113
63	105	109	107	111	109	112	111	113	114	115	115	117
64			113	115	115	117	117	118	118	119	119	120
65					120	119	122	120	123	122	124	123
66					125	121	126	122	127	124	128	126
67					130	124	131	126	132	127	133	128
68						126	135	128	136	130	137	132
69							139	131	140	133	141	135
70							142	134	144	136	145	138
71							147	138	149	140	150	142
72									154	145	155	147
73									159		160	
74									164		165	

*B represents boys.
*G represents girls.

United States Department of Interior, Bureau of Education

Fuel value of food must be considered. As you have seen, the body requires a certain amount of energy. The amount

Courtesy American Museum of Natural History

Fig. 77. A Sample Lunch

Cream of tomato soup, milk, white bread and butter, prunes, and cookies will furnish enough calories for hard work and play in the afternoon.

of energy furnished by foodstuffs is the *fuel value* of the food. This is measured in *calories*, one calorie being the quantity

Courtesy American Museum of Natural History

Fig. 78. A Sample Dinner

After a strenuous afternoon, a dinner of lamb stew, potato, spinach, whole-wheat bread, butter, milk, and rice pudding will suffice.

of heat necessary to raise the temperature of one kilogram (1000 grams) of water one degree centigrade. (1 kilogram

is equal to the weight of approximately 1 quart of water, or 2.2 lbs.) Or it may be defined as the quantity of heat required to raise the temperature of one pound of water about four degrees Fahrenheit. You can think of the calorie as the amount of heat from a gas flame which will warm a pound of water (about one pint) four degrees as measured with the ordinary household thermometer. By careful experimenting it has been found that one gram of each of the following kinds of food produces, when burned, or oxidized, in the body, the number of calories shown:

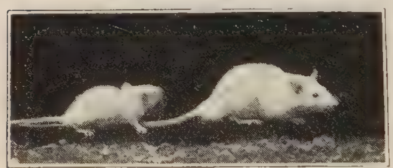
(*a*) 1 gram of protein produces 4.1 calories.
(*b*) 1 gram of carbohydrate produces 4.1 calories.
(*c*) 1 gram of fat produces 9.1 calories.

From these figures it is easy to determine the fuel value of a meal. All that you need to know is the percentage of protein, carbohydrate, and fat in each of the foods, and the weight of each kind of food which you eat. It would, of course, be very inconvenient and practically impossible in the home to determine the exact fuel value of each food which you eat, and thus select the correct amount of food for its fuel value. Scientists have done this for all foods. People who know how much food they need to keep in good health can, therefore, select foods of the proper fuel value.

The fuel value of foods required by different persons varies according to the factors already discussed, such as climate, age, physical exertion, and size. Standards have been worked out by experts in this field. A man doing moderately active muscular work requires about 3500 calories per day; a man doing light muscular work and a boy of 15 require about 3150 calories per day; a man at sedentary occupation, a woman at moderately active work, a boy from 13 to 14 and a girl from 15 to 16 years of age require about 2800 calories per day; a woman at light work, a boy 12, and a girl from 13 to 14 years of age require about 2450 calories; a boy from 10 to 11 and a girl from 10 to 12 years of age require about 1800 calories per day.

Of course, these standards are not to be considered exact for all people, but they furnish a guide by means of which we may regulate our daily diet.

Though you cannot measure the number of calories you require, you can see from this study that it is sensible to think about the fuel value of your food. Figure 80 shows the fuel value as well as the composition of some common foods. You can determine approximately the amount of food which makes you feel best, and then eat accordingly, knowing that overeating to satisfy an excessive appetite does you harm instead of good. Overfeeding the body is much like overfeeding a gasoline engine with a mixture which is too rich. It reduces the power of the machine and soon puts it out of running order.



Courtesy International Harvester Co.

Fig. 79. The Effect of Vitamines on Growth

The rat at the right was fed on foods that contained vitamines. During the same period of time the one at the left was fed foods that did not contain these vitamines.

Food must contain minerals and vitamines. Minerals are needed by the body to build cells, particularly those of bone and blood, to prevent certain diseases, such as scurvy and anæmia, to make digestive juices which prepare the food for the body's use, and in other ways to regulate the human mechanism. Most of our foods contain some minerals, but the principal supply comes from water, milk, and vegetables. Drinking water, as well as that contained in vegetables and fruits, carries with it minerals from the soil and rocks over which it passes before you use it. Since these minerals are a necessary part of one's bodily nourishment, your food must be selected so that you obtain a sufficient supply of them.

Certain substances called vitamines are necessary parts of a proper diet (Figure 79). Several kinds of these substances are known, all of which are required to keep the body growing

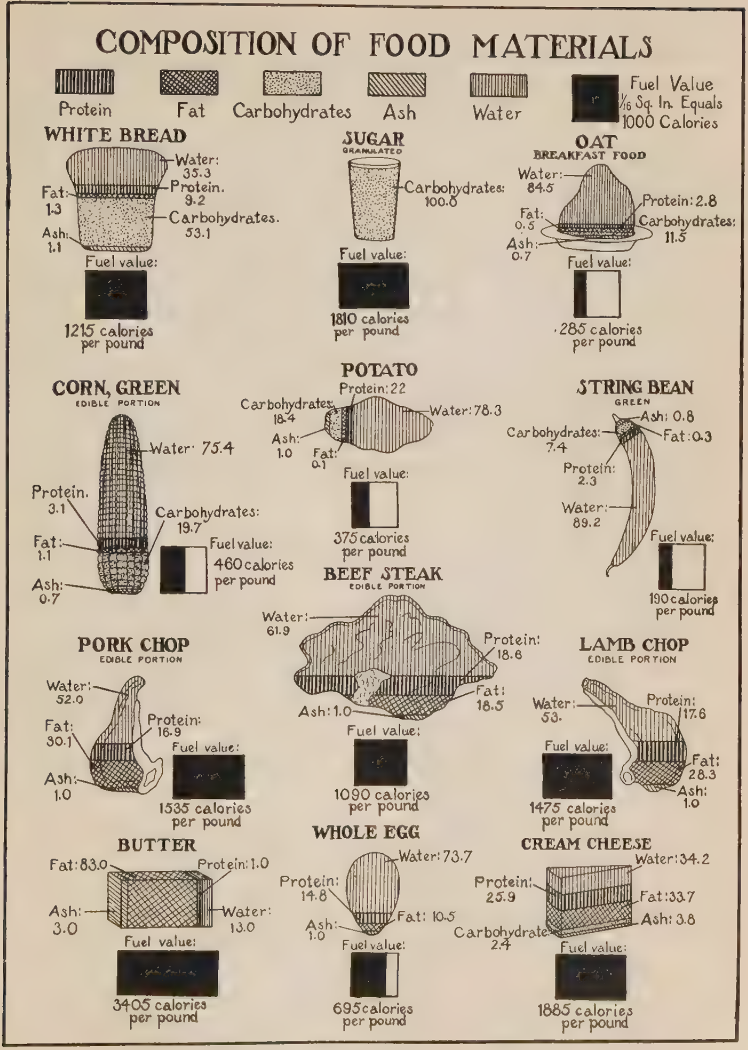


Fig. 80. Composition and Fuel Value of Foods

Which one of these foods has the greatest fuel value? Which one has the highest content of protein? Of carbohydrate? Of fat?

and in good health. One kind, called *Fat Soluble A vitamines*, is present to a considerable amount in milk, cod-liver oil, butter, eggs, and vegetables like lettuce and spinach. Another kind, known as *Water Soluble B vitamines*, occurs in milk, yeast, most vegetables, and in cereals made of whole grains. A third kind, *Water Soluble C vitamines*, is most abundant in fresh fruits and vegetables. Table IV shows the presence of these substances in some common foods.

The body requires a balanced diet. From the previous discussion you see that there should be considerable variety in your foods. A satisfactory diet requires that you eat such foods as will provide the correct proportion of fats, carbohydrates, proteins, minerals, and vitamines. In addition, you should drink plenty of water.

Table IV shows the composition of different kinds of food and their fuel value.

Exercise 9. The standard daily field ration of the American soldier is as follows:

bacon	12 oz.	potatoes	20 oz.	sugar	3.2 oz.
bread	18 oz.	prunes or preserves	1.28 oz.	evaporated milk	5 oz.
beans	2.4 oz.	coffee	1.12 oz.	vinegar	.16 oz.
salt	.64 oz.	pepper	.04 oz.	lard	.64 oz.
butter	.50 oz.				

Explain why this is a well-balanced ration. (See Figure 80 and Table IV.)

Exercise 10. Criticize these meals (Examine Table IV):

LUNCH	DINNER
Corn soup and crackers	Sirloin of beef
Creamed potatoes	Green peas
White bread	Cheese
Butter	Boiled-egg salad
Rice pudding	White bread
	Butter
	Milk

Exercise 11. Make up a daily menu of three meals which you think contain a well-balanced diet for the average person.

TABLE IV: FUEL VALUE AND COMPOSITION OF COMMON FOODS

PERCENTAGE COMPOSITION	KINDS OF FOOD MATERIALS			
	Fats	Carbohydrates	Protein	Water
Over 50%	*Butter (3515)† Salt Pork (3510)	Oatmeal Bread, white Rice Peas Beans Sugar		Pork, shoulder Eggs Salmon Milk Potatoes Apples Chicken
Between 25% and 50%	*Beef, rib (1790) *Mutton, loin (1755) Pork, shoulder (1680) Sausage, pork (2065) *Cheese (2070)	Peanuts	Cheese Peanuts Peas	Beef, rib Mutton, loin Sausage, pork Cheese Bread, white
Between 2% and 25%	*Eggs (721) *Salmon (965) *Oatmeal (1850) *Peanuts (2560) *Beans (1615) *Milk (325)	Milk Potatoes Apples	Beef, rib Mutton, loin Pork, shoulder Sausage, pork Eggs Salmon Chicken Oatmeal Bread, white Rice Beans Milk	Butter Oatmeal Peanuts Rice Peas Beans Sugar
Under 2%	*Bread, white (1280) Rice (1630) Chicken (540) *Peas (1565) Sugar (1820) *Potatoes (375) *Apples (315)	Butter Salt Pork Beef, rib Mutton, loin Pork, shoulder Sausage, pork Cheese Eggs Salmon Chicken	Butter Salt Pork Sugar Potatoes Apples	

*Vitamines are present in considerable quantity.

†Numbers after foods in first column indicate number of calories to the pound.

Water is necessary. Water is quite as necessary to the body as the foods which have been discussed. Though it does not oxidize to produce heat and energy, it does serve many purposes. First, it contains certain minerals which the body needs. Second, it helps to digest the food. Third, it makes it possible for digested food and blood to be carried to all parts of the body. Fourth, by means of the urine and perspiration it carries the waste products from the body, and fifth, it keeps the wastes of the bowels moist so that they can be removed. Doctors advise that every person drink at least six glasses of water a day.

Fig. 81. A Highly Magnified Section of Potato

If a very thin slice is cut from a potato and placed under the microscope, the cells of which it is made can be seen. Inside of the cells are oval grains of starch. They can be recognized by the markings on their surface.

PROBLEM 4: WHY ARE FOODS COOKED?

Cooking improves the taste and digestibility of foods. A mixture of flour, eggs, sugar, and milk before being cooked is not appetizing. But when the mixture is baked for a short time and becomes a batch of cookies or a cake, you would probably not pass it by. Similarly, you do not enjoy raw meat and raw potatoes, but a juicy roast and fluffy mashed potatoes satisfy the appetite. It is surprising what difference mere cooking makes in the taste of certain foods. Also by cooking, many foods may be better seasoned, and appetizing combinations of different food materials may be prepared for the table.

Cooking makes many foods more digestible. If you examine under a microscope the starch grains of a raw potato, they appear as in Figure 81. After they are cooked in boiling water or in the oven for a short time, they change their appear-

ance as shown in Figure 82. The cell walls around the starch grains are broken open. This allows the saliva in the mouth to come into more direct contact with the starch and to change it to sugar, which is one step in digestion. Cooking meat softens the fibers and tissues which hold it together. This allows the meat to be more easily cut and ground by the teeth before it is swallowed. The digestive juices in the stomach can then act on it more easily.

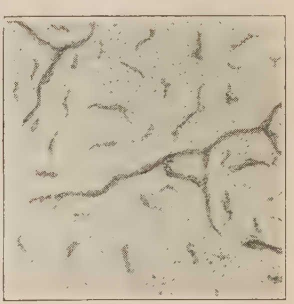


Fig. 82. A Slice of Cooked Potato Highly Magnified

Compare this figure with Figure 81. What is the difference between them?

Experiment 17: What effect does cooking have upon foods?

(*a*) Boil a small piece of potato in water for about fifteen minutes. Compare the boiled potato with raw potato. What changes have taken place?

(*b*) Cut away the peel of a potato. Scrape off a very little of the potato and place the scrapings on a clean glass slide. Examine the potato scrapings under a microscope. Note that the starch is in the form of tiny grains (Figure 81). Examine a slice of boiled potato under the microscope. Add a drop of iodine. How has the appearance of the starch grains changed?

(*c*) Boil a small piece of beef in water for thirty minutes. Compare the boiled beef with raw beef. In what ways has it been changed?

The action of heat on raw foods is brought about by five common methods: (1) cooking in hot water—*boiling* or *stewing;* (2) cooking in the hot air in the kitchen oven or over a camp fire—*baking* or *roasting;* (3) cooking in the flames or directly over the fire—*broiling;* (4) cooking in hot fat or grease—*frying;* (5) cooking in steam—*steaming.*

The proper use of these different methods is a science and an art which have been studied for many years. Much food is made indigestible and useless to the body by improper cook-

ing. The best directions for cooking are contained in good cook-books, which should be consulted by one who does not know the principles of preparing food for eating.

Exercise 12. Consult a good cook-book to find as many important principles of cooking as you can, and make a list of them. After each give a reason for the method used. Your list will include the following, which are given as samples to show you what is wanted:

1. The method of cooking which makes food most appetizing and digestible is the best method, because the body can then get the greatest value from it.
2. Some vegetables should not be cooked for a long time, because the vitamines are destroyed.
3. Some vegetables should be cooked in open vessels, because this allows........ (complete this and then add others), etc.

Fig. 83. The Trichina Worm

If pork is not thoroughly cooked, the worm may remain alive and cause a serious disease.

Cooking makes foods safe. Germs and other disease-producing organisms are sometimes present in certain foods. Raw oysters, milk, and celery have been the cause of many deaths from typhoid fever. Raw pork, which may contain small worms called *trichinæ* (Figure 83), is always a source of danger. Uncooked beef may carry into the human body tapeworms, as well as the germs which cause tuberculosis and foot-and-mouth disease. Proper cooking or heating will destroy these harmful living things and make the food safe.

There is another way in which cooking may make foods safe. Certain organisms in the food cause the food to spoil. During the spoiling or decay, poisons may be produced. These poisons, taken into the body with the spoiled foods, may cause what is commonly called *ptomaine poisoning*. Proper cooking of the fresh food destroys the organisms and thereby keeps the food from spoiling and free from poisons. The heat may also destroy the poisons in spoiled food, but it is not a safe policy to depend upon this.

Exercise 13. State four reasons why foods are cooked.

1.................... 2.................... 3.................... 4....................

Exercise 14. Make a list of cooked foods which you eat, and after each state the method of cooking generally used. Which is the most common method? Why is this so?

PROBLEM 5: HOW ARE FOODS KEPT FROM SPOILING?

Foods must be protected from living organisms. Raw foods, whether from plants or animals, must be properly cared for or they begin to spoil, or decay, in a short time. Millions of dollars' worth of food is wasted every year on account of careless handling. To prevent this decay the food must be protected against the living organisms which get into it and change its composition. This change is called *decomposition*, for the materials in the food-stuff are really broken up, forming new materials. These give the food a bad taste or a bad odor, and often cause it to become poisonous.

How harmful organisms get into food was a mystery for a long time. But gradually it became known that three kinds of organisms may come from the air, as shown by the following experiment.

Experiment 18: To show that living organisms may get into exposed foods.

(*a*) Moisten a slice of bread. Expose it for a half-hour and then place it in a fruit jar or dish. Cover the jar or dish so that the bread will remain moist, and keep it in a warm place. Examine it from day to day. At the same time put into another jar a slice of fresh unmoistened bread. Compare the two slices of bread for at least a week. What do you conclude?

(*b*) Make one pint of a solution of corn syrup or molasses, using about one-tenth as much syrup as water. Divide this into three portions. Place one portion in an open vessel in the ice-box. Put the second portion in a vessel and boil it for a half-hour; then cover the vessel air tight and set it in a warm place. Leave the third portion in an open vessel in a warm place. Examine the different solutions from day to day. Can you explain the results?

Usually two kinds of plant growths appear on moist bread, *molds* and *bacteria*. There are many varieties of each. You may observe at least two molds on the bread. The most common is the cotton-like material covered with black dots, called bread mold (Figure 84). Another common variety is the blue mold. If you examine these molds under the microscope, you will see that they bear *spore cups* containing hundreds of *spores* (Figure 85). Each of these spores, like seeds, can produce a new plant when it comes into contact with warm, moist food, on which it can grow. Here and there on the bread you may see other spots where the bread becomes yellow or discolored, and pasty. Some of these are caused by bacteria (Figure 175, page 200). The bacteria also produce spores, but not in the same way as the molds. These spores of bacteria and molds are so small that they may be carried in the air and thus get into our foods. As they grow and decompose the food, it becomes foul-odored and worthless.

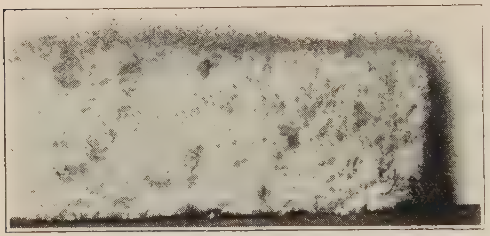


Fig. 84. Bread Mold

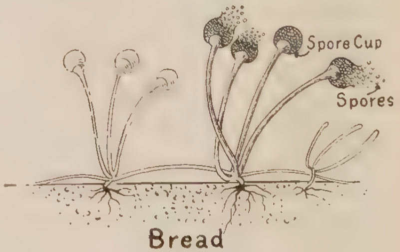


Fig. 85. Spore Cups and Spores of Bread Mold

When the walls of the spore cups break, countless millions of spores are set free in the air.

While mold may appear on the warm exposed syrup solution used in Experiment 18, there will also be seen small bubbles of gas rising from the solution. In time the syrup will smell sour. These changes are caused by *yeasts*. Under the

microscope they appear something like Figure 86. These plant organisms feed on the sugar and change it to alcohol and carbon-dioxide gas. This process is called *fermentation.* The gas causes the bubbles which you see. The alcohol is changed to vinegar (acetic acid), which causes the sour odor and taste after it has stood for several days.

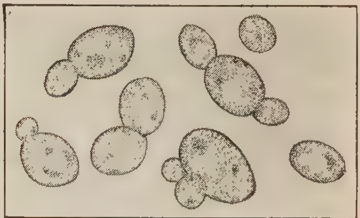


Fig. 86. Yeast Plants

These microscopic plants cause fruits and fruit juices to ferment.

Exercise 15. From Experiment 18 and your reading explain several ways by which foods might be prevented from spoiling.

The air is not the only source from which destructive organisms enter our food. They exist nearly everywhere. Impure water, dirty hands, and unclean vessels used in washing or handling food materials may be the carriers of the organisms which spoil food, produce poisons, and cause disease. Flies and other insects also act as car-

Courtesy Chicago Department of Health

Fig. 87. A Sanitary Meat Market

The meat is protected from decay and germ-carrying insects by being kept either in glass-covered cases or in refrigerators.

riers. It is clear that care in keeping food free from decay is absolutely essential to our pocketbooks and to our health.

There are five important ways to keep food from spoiling. First, proper handling and storing of food are necessary. A few illustrations will suggest to your minds many things which you can do to keep food pure. Foodstuffs should be kept covered, particularly in the market, the restaurant, the fruit stand, and the home (Figures 87 and 88). In picking and marketing fruit or vegetables, nature's covering, such as the

Courtesy Chicago Department of Health

Fig. 88. Another Kind of Meat Market

What is wrong with the meat market shown in this picture?

peel, or skin, or husk, should not be broken or cut. Potatoes, turnips, beets, and other vegetables should not be stored in moist, warm places. Milk should be protected by sanitary milking, by shipping in clean cans, by using absolutely clean bottles, and by *pasteurization.*

Experiment 19: How is milk pasteurized?

(*a*) Fill a test tube half full of milk. Place the test tube of milk in a beaker of water (Figure 89), and heat the beaker with a small flame. Take the temperature of the water in the beaker

and regulate the flame so that the temperature will remain at 144°F. Heat for 30 minutes at this temperature.

(*b*) Plug the tube of milk with a little cotton and set it aside. Fill another test tube half full of unpasteurized milk and set it aside with the pasteurized milk. Taste the milk in both test tubes every day for several days. Which milk remains sweet longer?

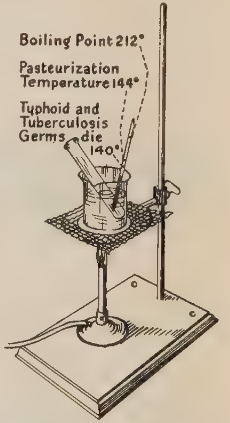


Fig. 89. Pasteurizing Apparatus

Why will pasteurization preserve milk?

You can pasteurize milk at home by using the apparatus shown in Figure 90. To do this you will need an iron pail fitted with a false bottom. This false bottom may be made by obtaining a piece of tin slightly larger than the bottom of the pail and cutting several holes through it. The false bottom is necessary to prevent the bottles from breaking. Fill the pail with water so that the level is about the same as that of the milk in the bottles, and heat to a temperature of 144°F.

Exercise 16. Make a list of different ways by which various foods can be protected in handling and storing.

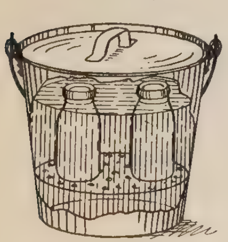


Fig. 90. Home Pasteurization

Second, foods may be preserved by cooking and canning. The bacteria, yeasts, and molds are killed by being heated to a high temperature. Thus fruits, vegetables, fish, and meat are cooked in boiling water, and while hot, packed in cans, or they may be placed in cans while raw, and then heated. By either method the heat cooks the food and kills the germs. The cans are sealed with paraffin or with other air-tight covers to prevent new organisms from entering. This also keeps out air, which is necessary for growing organisms. Meats are often cooked (fried or roasted), placed in jars, and covered

with hot lard which, when cool, protects the meat from spoiling. Often sugar or salt is added to season the food and to help preserve it.

Exercise 17. Consult a cook-book and give the best ways to can or preserve cooked foods. For example, cherries: place in jars with correct amount of sugar; put the jars in hot water for 40 minutes, seal while hot, and stand jars upside down until cold.

Keystone View Co.

Fig. 91. A Cold Storage Room in a Packing House

After the animals have been "dressed" and inspected, they are hung in cold storage rooms to keep them from decaying.

Third, foods may be preserved by adding certain chemicals which prevent the growth of organisms. This practice is not objectionable if the preservatives themselves are not poisons. Sugar, spices, salt, and vinegar are often used in home canning and are not dangerous. Meats are salted in brine, and smoked. In canning and packing houses some poisonous substances have in the past been used, but the United States Government now requires that preserved foods bear labels stating exactly the kind and amount of preservative contained in the food.

Exercise 18. Make a list of all preservatives used at home.

Exercise 19. Examine the labels of factory-canned foods. Name the preservatives listed and state the amount of each used.

Fourth, drying certain foods protects them from decay. You recall that moisture and warmth are necessary for the

growth of bacteria and other organisms. You can understand, then, why dried fruit, vegetables, and meat are not easily spoiled.

Exercise 20. List different foods that are dried to keep them from spoiling. (Ask your grocer.)

Fifth, organisms can be kept from growing by keeping food at a low temperature (Figure 91.) In the home the refrigerator is used for this purpose. The air in the refrigerator circulates, as shown in Figure 92, and, as long as ice is present, the food is kept cool. Many foods must be shipped in refrigerator cars (see Figure 61). When uncanned food is stored for any length of time, it is kept in cold storage rooms. Also, many canned foods are placed in cold storage.

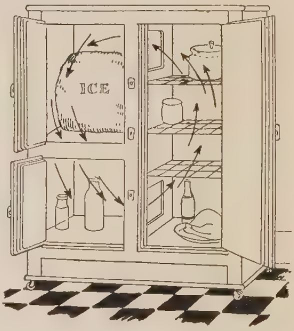


Fig. 92. Air Currents in a Refrigerator

The walls of refrigerators are very thick and are filled with materials which will not allow the outside heat to enter. As the ice melts, it takes heat from the surrounding air and the food. How do you account for the circulation of air shown by the arrows? (See page 57.)

Exercise 21. Make a section drawing of your home refrigerator. Indicate the direction of air currents by arrows after you have carefully examined the construction of the interior. Explain your drawing. (See page 57.)

Exercise 22. Make a topical outline of Problem 5, including all points that you consider worth knowing.

Review Exercise on Unit III. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit III and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT III

1. Explain how your food supply is dependent upon the sun.

2. Expose a freshly-cut apple in a warm place and cover it to keep it moist. How does the mold which grows compare with that which forms on moist bread?

3. Why do inhabitants of Arctic regions eat so much fat?

4. If a hard-working man were forced to live on milk for a time, how much milk should he drink daily to get the proper number of calories? (Consult Table IV, page 99.)

5. Keep a record of the food you eat for one day. Ask your teacher to criticize your diet.

6. Why is milk a well-balanced food?

7. Place a little sugar in a test tube and heat over a flame. Describe what happens.

8. Explain why solid material collects in a teakettle when nothing but clear water has ever been put into the kettle.

9. How could you prove that potatoes contain a large amount of water?

10. Make a list of the good eating habits which you intend to follow.

11. Make a survey of your local groceries and meat markets to see if they use the proper methods of protecting foods which spoil easily.

UNIT IV

OBTAINING A GOOD WATER SUPPLY

Preliminary Exercises

1. Name as many sources of water supply as you can.
2. Make a list of the uses of water under the three headings given in the table below.

Uses of Water

HOME	INDUSTRIAL	COMMUNITY
Cooking etc.	Making steam etc.	Cleaning streets etc.

3. What factors would you consider in determining whether a town or city has a good water supply?
4. What is the source of water in your home? How is it brought from the source to your kitchen?
5. What becomes of the water which falls on the earth as rain?
6. Describe water.
7. A pipe 100 feet long reaches from a cliff to a spring below. How high will the water rise in the pipe above the water in the spring, if all air is removed from the pipe?
8. Name all the different devices which you know that are used to distribute and regulate the supply of water in your home.
9. Upon what does the shape of a body of water depend?

THE STORY OF UNIT IV

We have become so accustomed to the thousand and one ways in which man has improved his original environment, that it is hard to realize that there are only three necessities without which life cannot exist: air, water, and food. Studies which have been made of the life of primitive man show that

he lived in regions which were supplied with natural bodies of water, such as lakes, rivers, and springs. It was probably an accident when man first discovered that water could be obtained by digging in the ground. This knowledge must have meant a great deal to him, for it made him independent of streams, lakes, and springs. Until recently the shallow well dug by hand was the only method of obtaining water from

Courtesy Holway Engineering Co.

Fig. 93. A Water-Supply Reservoir

To secure pure water for the city of Tulsa, Oklahoma, a dam was built across Spavinaw Creek, a stream which flows in a gravel bed from cold springs high up in the Ozark Mountains. The dam is 3500 feet long and 55 feet high. It made a lake 6 miles long, holding 20,000,000,000 gallons of water.

the ground, but modern machinery has enabled us to bore into the earth to great depths, and water may be obtained in regions which were formerly thought incapable of supporting life. The development of any region is dependent upon a source of water, for without it life cannot exist.

A good water supply must provide plenty of water for all purposes. In country districts water is usually near at hand, but many cities must go long distances to get a sufficient amount. Table V shows the enormous quantity of water needed to supply certain large cities.

Table V: Water Consumption of American Cities (1924)

CITY	POPULATION	GALLONS USED DAILY	GALLONS USED DAILY PER PERSON
Des Moines, Ia.....	140,923	11,527,142	81.8
Kansas City, Mo...	372,200	46,932,798	126.1
Omaha, Nebr......	204,382	26,427,000	129.3
Boston, Mass......	789,900	87,680,000	111.1
Los Angeles, Cal...	666,853	121,000,000	181.4
Chicago, Ill........	2,886,121	823,691,694	285.4
New York City....	6,024,400	789,200,000	131

In order to supply this enormous demand many cities have bought huge areas of land and have built reservoirs to collect the water. Others have dammed rivers, sunk wells, or

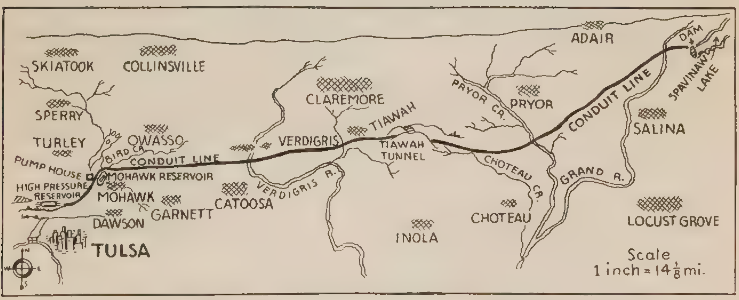


Fig. 94. Carrying Water from Reservoir to City

A 53-mile pipe-line carries the water from Spavinaw Lake to Tulsa. The pipe is made of reënforced concrete, is 5 feet in diameter, and will supply 25,000,000 gallons of water a day. Notice how the line travels across streams and through hills. The water flows by force of gravity, the top of the dam being 90 feet above the city.

tapped lakes (Figures 93 and 94). As a city increases in population, new sources of supply must be discovered in order to meet the needs of everyone.

Many cities have an abundant supply of water, but no efficient method of distributing it. In order to supply all

parts of the city, a system of pipes, or *mains*, is laid, sufficient in size to meet the needs of the locality served (Figure 95). But with the increase in population and business, buildings are made higher and set closer together, and thus a larger number of people are crowded into a given district. The old mains, therefore, must be replaced by larger ones, capable of delivering a larger volume of water. The demand for water varies with the time of the day (Figure 96). During some parts of the day many systems cannot pump enough water to meet the requirements; as a result of this the higher floors of buildings cannot be supplied. To meet this demand many cities have constructed reservoirs at high points in or near the city. These supply sufficient water for fighting fires, and they also furnish a reserve to meet the needs during the rush hours of the day.

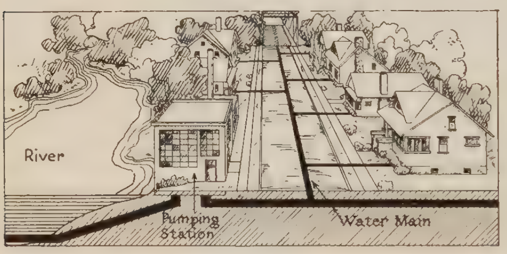


Fig. 95. Water-Supply System of a Small City

The water is pumped from the river or lake into the mains. Small pipes carry the water from the mains to the houses.

Another requirement of a good water supply is that the water be pure. Water which is obtained from shallow wells is frequently impure because surface impurities seep into the well. Streams become *polluted* by materials which wash into them from the banks, or by the sewage of cities. Water obtained from these unsafe sources contains germs which are responsible for typhoid fever and other diseases. In cases where the source of water is unsafe, it is necessary to provide some method of removing the germs and other impurities.

A very desirable feature of a good water supply is that the water be *soft;* that is, it should not contain certain minerals

dissolved in it. Soft water is especially desirable for laundering, because it requires but little soap to make good suds. When hard water is used in boilers to make steam, the minerals remain in the boilers and form a deposit called "boiler scale." This scale causes the boiler to heat unequally, and also increases the amount of fuel required to heat the water. For these reasons it is very desirable that the water be soft if it is used for home and industrial purposes.

The efficient distribution of water and the purification and softening of water for drinking and industrial purposes

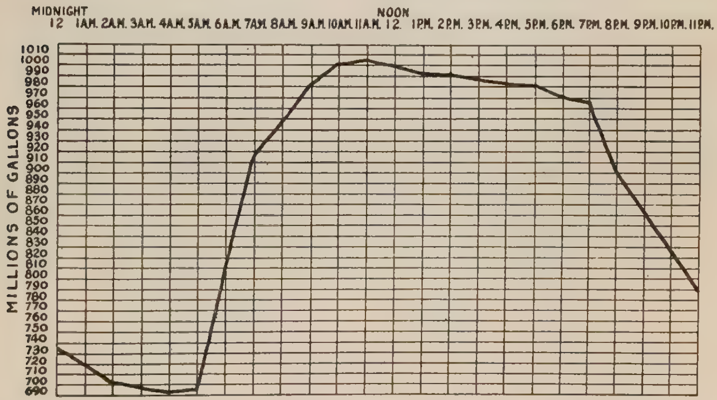


Fig. 96. Daily Pumpage by Hours—City of Chicago

The figures of the graph represent the rate of pumping water for the city of Chicago on May 4, 1925. For example, at 12 noon, water was being pumped at the rate of 1,000,000,000 gallons per hour.

require a large expenditure of money. Yet, to the essentials of a good water supply which have already been mentioned, we must add the requirement that it be cheap enough so that all can use it. Securing a good water supply is a problem which involves the consideration of many factors and requires the advice and skill of experts. One of the clearest signs of a progressive community is a plentiful and wholesome water supply as well as an efficient method of distribution.

PROBLEM 1: WHAT ARE THE IMPORTANT SOURCES OF WATER?

Our water supply is dependent upon the rainfall. There are two principal sources of water supply, *surface water* and *ground water*. Both of these sources of supply are dependent upon the rainfall. When rain, or any other form of water, strikes the ground, one of three things may happen to it: it may run off into streams, lakes, or ocean; it may sink into the

Courtesy St. Louis Department of Public Utilities

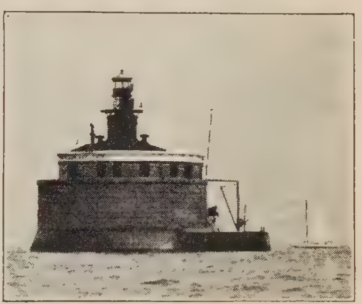
Fig. 97. Settling Basins—St. Louis, Missouri

Water is pumped from the Mississippi river into these basins, where some of the impurities settle to the bottom. (See Figure 129.)

ground; or, it may evaporate into the air. A light rain falling in the forest or upon grass lands may nearly all soak into the soil. A heavy rain falling on the same land will run off, in part, into nearby streams. The heaviness of the rainfall, the amount of vegetation, the slope of the land, the temperature of the air, the kind of soil upon which the rain falls, all determine what happens to the water. We are interested in the part which flows into the streams and that which sinks into the soil, because this furnishes our water supply.

We obtain water from many sources. Probably the most satisfactory source of water supply is that furnished by mountain lakes and streams. The water obtained from these sources is generally pure, and, if obtained from high up in

the mountains, it is not necessary to use pumps to bring it to the city and force it through the mains. New York City, not situated in a mountainous district, has bought over 900 square miles of mountainous land and has constructed reservoirs to collect the water which falls upon this area.



Courtesy W. H. Duffney

Fig. 98. A Water-Supply Crib

This crib in Lake Michigan helps furnish water for the city of Chicago.

Rivers furnish an abundant supply of water, but in most instances it must be purified before it can be used. In some cases the water is pumped directly from the river to *settling basins* (Figure 97) where the impurities are removed. In other cases wells are sunk along the banks of the river, and the water is partially purified by seeping through the soil.

Large lakes, such as the Great Lakes, furnish an abundant and safe source of water if proper precautions are taken. In Chicago and other lake cities, *cribs* (Figure 98) are built out in the lake where the water is very deep and practically free

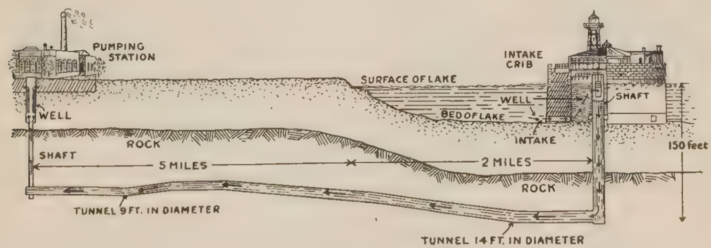


Fig. 99. From Crib to Pumping Station

How high will the water rise in the well of the pumping station?

from impurities. Huge tunnels dug under the lake bed bring the water to pumping stations on the shore, from which the water is pumped throughout the city (Figure 99).

In the sources of water which we have discussed, the supply has been kept up largely by that part of the rain which flows off. The part which sinks into the ground furnishes another source of supply, which we obtain by sinking *wells*. The rain which soaks through the soil sinks until it reaches solid rock and can go no further. It then remains between the particles of soil just above the rock. This part of the soil is called the *water table* (Figure 100). Wells are sunk into this water table. Since the water table obtains its water from the rain which soaks through the ground, the level of the water table varies at different times of the year. This is the reason why some wells become dry during the hot summer months.

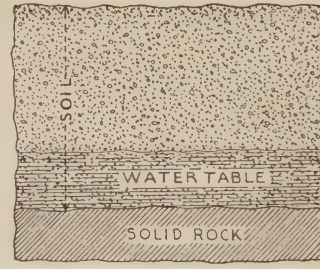


Fig. 100. A Section of the Earth Showing the Water Table

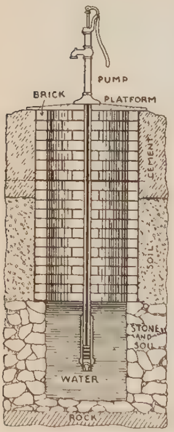


Fig. 101. A Shallow Well Correctly Constructed

Except near the bottom, the sides of the well are made of brick cemented together.

Experiment 20: How does the water which soaks into the ground get into a well?

(*a*) Fill a tumbler with small stones. Push a six-inch length of glass tubing down between the stones near the side of the tumbler to within a half inch of the bottom. Fill the tumbler about half full of water. How does the water get into the glass tube? How does the height of water in the tumbler and in the glass tube compare?

(*b*) Put a piece of glass tubing in a tumbler. Fill the tumbler full of sand, taking care that the glass tubing is visible from the outside of the tumbler. Slowly pour some muddy water on the sand. Compare the clearness of the water which was poured into the tumbler with that of the water which filtered through the sand into the tubing.

Exercise 1. Figures 101 and 102 show two shallow wells. Which furnishes the safer source of water? Why? Refer to Experiment 20.

Deep wells furnish us with pure water. Water sometimes seeps into the solid-rock layer through cracks and crevices and enters porous layers of rock, like sandstone, underneath. The water, having passed through a great depth of soil, is thus freed from impurities. Now, if we sink a well by driving a pipe through the soil and non-porous rock into the porous-rock layer, water will rise in the pipe to the level of the top of the water table. This type of well is called a *deep well*, or driven well. Wells of this type are much more common today than those dug by hand. In addition to the fact that there is much less danger of the water's becoming impure, these wells are not so liable to go dry during the summer season.

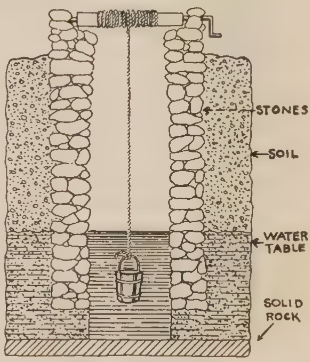


Fig. 102. A Shallow Well Poorly Constructed

The sides of the well are made of loose stones.

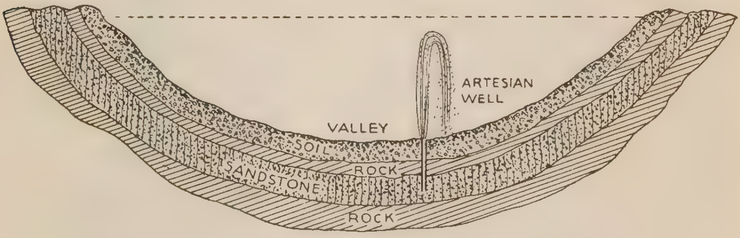


Fig. 103. Conditions for Producing an Artesian Well

Water enters the porous sandstone layer where it comes to the surface. In one place a layer of porous rock may come to the surface, and in another place the same layer may be buried beneath hundreds of feet of soil or rock.

If the water enters the porous layer at a much higher point than the well (Figure 103), the water may come to the surface

or even spout into the air when the hole is drilled (Figure 104). Such wells are called *artesian wells*. Since the water must seep through many miles of porous sandstone, the impurities are usually *filtered* out. Water from deep wells and artesian wells is, therefore, usually safe for drinking purposes.

U. S. Geological Survey

Fig. 104. Artesian Well in South Dakota

A stream spouts 100 feet into the air, the water entering a sandstone layer in the Black Hills many miles away.

Exercise 2. Which of the sources of water mentioned in this problem will best meet the five requirements of a good water supply for a rural community? Explain why the sources which you have given for rural communities will not meet the requirements for a city supply. (See the Story of Unit IV.)

Exercise 3. Describe the source of your local water supply.

PROBLEM 2: HOW DO PUMPS WORK?

The lift pump uses air pressure. The common pumps which are used to raise water from wells are called *lift pumps* because they lift the water out of the well. Figure 105 shows in section the principal parts of a lift pump. The *piston*, fitted with a leather washer to make it water tight in the *cylinder*, is moved up and down by the *piston rod* when the *pump handle* is forced down and up. A *valve* (Valve 1) is placed in the shaft just below the pump cylinder. There is also a valve (Valve 2) in the piston. An experiment will make clear the construction and operation of the pump.

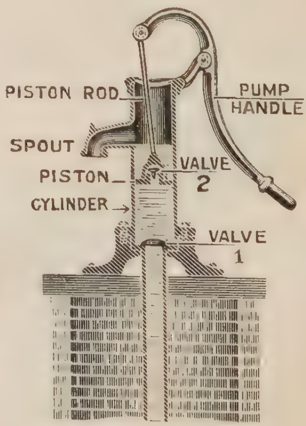


Fig. 105. A Lift Pump

Experiment 21: How is a lift pump constructed and operated?

(*a*) Obtain a glass tube one or two inches in diameter and twelve inches long. (A lamp chimney with straight sides will serve.) Fit a one-holed cork in the lower end. Cut a piece of rubber sheeting or oilcloth slightly larger than the hole in the cork. Place the rubber over the hole in the cork, fastening it at one side with a tack. This makes the lower valve (Valve 1, Figure 106). To make the piston obtain a two-holed cork slightly smaller than the inside of the glass tube and wrap thread around it until it fits snugly inside the glass tube. Construct a valve of rubber sheeting or oilcloth over one hole in the piston. Into the other hole force a round wooden stick about 16 inches long, and fasten it securely to the cork by means of pins, as shown in the figure. This forms the piston rod. Now fit a two-holed stopper to the upper end of the glass tube. The piston rod slides through one of the holes. Bend a glass tube six inches long into a right angle and insert this in the other hole. This makes the spout.

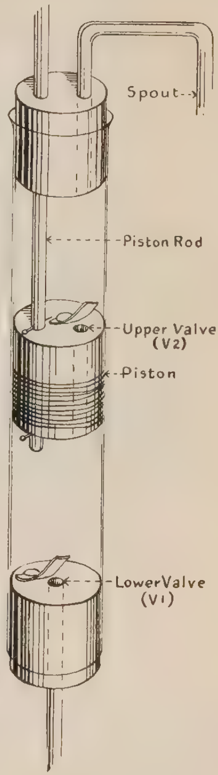


Fig. 106.
A Homemade Lift Pump

(*b*) Push the piston down and pour a little water into the cylinder after loosening the upper cork. Place the cork in position again and pull the piston upward. Does the lower valve open or close? Does the valve in the piston open or close? Observe that the water follows the piston upward. (It may be necessary to move the piston up and down several times.)

(*c*) The space under the piston is now filled with water. Push the piston down. Describe the operation of the valves. How does the water get above the piston?

(*d*) The water is now above the piston. Raise the piston and note which valve is open and which valve is closed. How does the water get out of the pump?

You can now tell how the pump works, but can you tell why the water rises from the well when the piston moves upwards? Water does not run up-hill, nor does it rise in a pipe unless it is forced.

Experiment 22: What is the force which causes the water to rise in the pipe?

(*a*) Fit a test tube with a one-holed cork. Insert a piece of glass tubing about two feet long in the cork so that it will extend down to the bottom of the test tube. Fill the test tube with water and insert cork. Apply your lips to the glass tubing and try to "suck" the water up into the glass tube. Do you succeed in doing this?

(*b*) Loosen the cork so that the air can get into the test tube above the water, and repeat. Does the water rise in the tube?

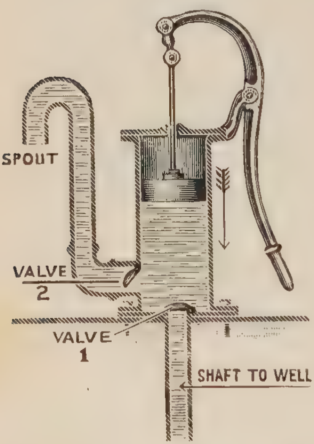


Fig. 107. A Simple Force Pump

The experiment shows that water will rise in a tube or pipe from which the air has been removed, provided that the outside air can get to the water around the pipe. This experiment will give you a start on answering the question, "Why does the water come up from the well?" The air pressure on the outside presses on the water in the well. The air presses down inside of the pump also, but it presses against the top of the piston and not on the water below the piston. The piston fits air-tight in the cylinder. When it is raised, it tends to leave below the piston a space which contains no air. The air pressure on the water in the well, thus being greater than the air pressure on the water below the piston, forces the water up from the well into the cylinder of the pump, just as it forces mercury into a tube from which air has been removed. (See page 58.)

Exercise 4. Make three drawings showing the position of the valves and the movement of the water during (1) the first upstroke of the piston, (2) the downstroke of the piston, and (3) the second upstroke of the piston. Explain each drawing, giving your reason for the position of the valves and the movement of the water.

The force pump pushes the water out. When it is necessary to supply water at a higher level than the pump, *force pumps* are used instead of lift pumps. The simplest type of force pump is shown in Figure 107. When the piston is pulled upward, Valve 2 closes, and water rises in the pump, forcing Valve 1 open, as in the lift pump. On the downward stroke of the piston, Valve 1 is closed by the pressure above it and Valve 2 opens, allowing the water to be forced through the spout. Since the water flows only on the downstroke of the piston, this type of force pump cannot be used where a steady stream is desired.

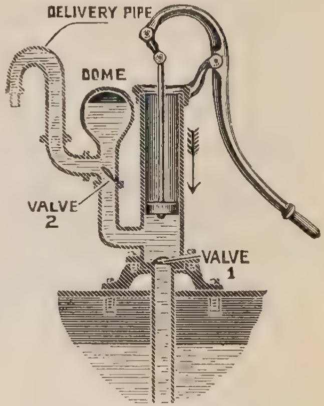


Fig. 108. An Air-Dome Force Pump

Exercise 5. What is the difference between the construction and operation of the lift pump and the force pump?

Some force pumps throw a steady stream of water. The *air-dome* force pump (Figure 108) is a pump of this type. It is constructed like the common force pump, but has one additional part, the air-dome. As the piston moves down, the water is forced through Valve 2 more rapidly than it can flow from the small spout. The excess water is forced into the air-dome, pushing the air into a smaller space. When air is pushed into a smaller space, or *compressed*, it exerts an outward pressure. On the upstroke of the piston, Valve 2 closes and the water continues to flow. Why? Such pumps

are used for small water supplies and in fire engines where it is necessary to force a continuous stream of water to great height.

Exercise 6. Explain why the air-dome force pump throws a steady stream of water.

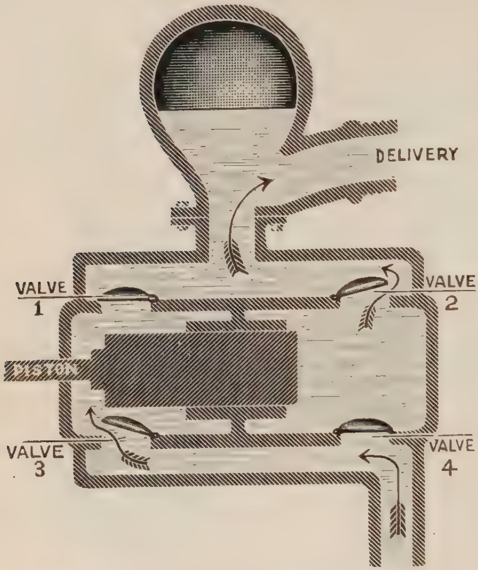


Fig. 109. A Double-Acting Force Pump
Note that there is water on both sides of the piston. The piston is shown moving to the right.

The *double-acting* pump (Figure 109) is commonly used in city pumping systems and on fire engines. There are two intake valves, Valve 3 and Valve 4, and two outlet valves, Valve 1 and Valve 2. The piston moves back and forth between these two sets of valves, propelled by steam, gas, or electric power.

Exercise 7. Summarize the action of the double-acting pump by answering the following questions: What is the position of each valve (that is, is it open or closed) when the piston moves to the right? What is the position of each valve when the piston moves to the left? Give your reasons for each answer.

PROBLEM 3: WHY DO CITIES CONSTRUCT RESERVOIRS AND STANDPIPES?

When one is touring through the country by automobile or train, the first indication of a city or town is usually the sight of a reservoir or standpipe. Standpipes are constructed in

various ways. Some are steel cylinders with straight sides (Figure 110). Others are small tanks or reservoirs held up in the air by a steel framework (Figure 111). These reservoirs are filled with water from pipes which come from the source of supply. The kind of standpipe used depends upon the size of the city. Why are these reservoirs and standpipes usually located at the highest place in a city or town?

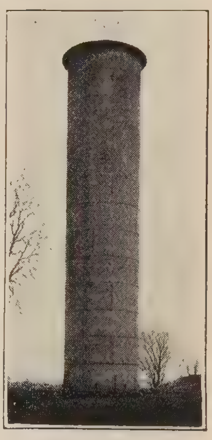


Fig. 110.
A Straight-Sided Standpipe

This standpipe is 100 feet high and 22 feet in diameter. How many gallons of water does it hold? (One gallon equals 231 cu. in.)

Experiment 23: How high will water rise in pipes connected with a reservoir or standpipe?

Connect to a large pail or jar, fitted with a stopper through a hole in the bottom, a long rubber delivery tube. Place the jar on a high table or cabinet several feet above the level of the sink or open window. Close the end of the delivery tube with a clamp, or bend the tube so that the water cannot flow through it. Fill the jar with water. Attach to the end of the delivery tube an upright glass tube, three-eighths or one-half inch in diameter, and long enough to reach above the level of the water in the jar. The jar represents a reservoir or standpipe, and the delivery tube may be considered a water or service pipe.

(*a*) Open the pinch clamp slowly. How high does the water rise in the delivery tube?

(*b*) Substitute for the large glass tube one of smaller diameter. Repeat (*a*). Does the diameter of the water main determine how high the water rises?

(*c*) Substitute for the large jar a much smaller jar and repeat (*a*). Does the diameter or volume of a reservoir determine the height to which the water rises?

Summarize the results of this experiment.

Exercise 8. On the basis of Experiment 23 explain how the water in artesian wells (page 119) is forced into the air.

In some cities which have tall buildings the city reservoir is not high enough to supply water to the top floors. These buildings generally have a small reservoir placed on top of the building. Water is pumped into this tank by force pumps. The pipes which carry water to different parts of the building are connected with the tank so that water may be supplied to the top floors.

Fig. 111.
Supported-Tank Type of Reservoir

A standpipe or reservoir keeps an even pressure throughout the system. When pumps are used to keep the water flowing through the mains, the water will rise to different levels at different times of the day, because the amount of water used at all hours is not the same. An abundant supply of water is especially needed in case of fire. Some cities which have pumping systems use also a reservoir or standpipe so that an abundant supply of water is always on hand in case of fire or a "break down" of pumps. Standpipes and reservoirs in connection with pumping systems insure a supply of water when it is most needed.

Fig. 112. Diagram of a Small-City Water-Supply System
Note the pumping station on the bank of the river.

Exercise 9. Figure 112 is a diagram of the water-supply system of a small city. Copy this diagram and draw the pipes which connect the different parts of the system and the buildings. Show the direction of the water by means of arrows.

PROBLEM 4: HOW IS THE FLOW OF WATER CONTROLLED IN OUR BUILDINGS?

Faucets control the flow of water. In order that the water may not be wasted, it is necessary that we have some devices to turn it on and off when we use it. This is commonly done by means of *faucets* and *flush-tanks.*

Figure 113 shows a section of the commonest type of faucet. The handle is seen to be attached to a screw which fits into the upper part of the faucet. The lower end of this screw is usually faced with a flat fiber or leather washer. This flat washer covers the circular opening, or seat, at the bottom.

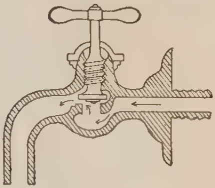


Fig. 113. A Screw Faucet

If the handle is turned, the washer is raised and the water can flow through the opening. When the faucet is turned off, the screw forces the leather washer down against the opening and the water is shut off. The handle rod usually has some packing of cotton twine around it. Sometimes this packing gets loose and the faucet leaks. Also, after a time the fiber washer may get worn, and the water will trickle out. In order to prevent this waste of water, all of the working parts of the faucet must be kept in good condition.

In our houses we are careful to see that the faucets are not left open, but in hotels and in other public places much water is wasted if the screw type of faucet is used. To control this, self-closing faucets have been devised. Figure 114 shows a common type of this faucet. When the handle is turned, the screw causes the plunger to move upward, compressing the spring. The spring forces the plunger back when the handle is released, shutting off the water.

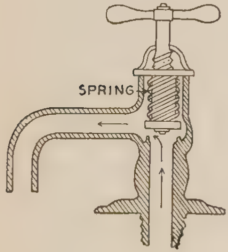


Fig. 114. A Self-Closing Faucet

Exercise 10. Figures 113 and 114 show the parts of faucets when they are open. Make a drawing of each type of faucet when it is closed. Label the parts.

Modern houses have flush-tanks. One of the necessary sanitary devices for controlling the water supply in the house is the flush-tank, connected with the toilet (Figure 115). The flush-tank is generally located on a pipe above the toilet, but in some cases it is built into the wall. If you remove the lid of the tank, you see a hollow copper ball about four inches in diameter. This ball floats on the water. By pulling on a chain, pressing a button, or turning a lever, the outlet valve is opened, and the water flows down into the bowl. As the water sinks, the copper ball sinks with it and opens the inlet valve, which is attached to the other end of the rod connected with the ball, and the water enters the tank. The outlet valve slowly sinks back into position and closes the opening into the bowl, and the tank fills with water. The copper ball rises with the water, closing the inlet valve, and the tank is ready to repeat the operation. At times, on account of their worn condition or improper adjustment, these valves may not completely shut off the flow of water into the tank or into the bowl. The bowl is so constructed that all of the water does not flow out through the drainpipe. The water which remains in the bowl prevents the odors of sewer gas, which may be in the drainpipe from entering the room.

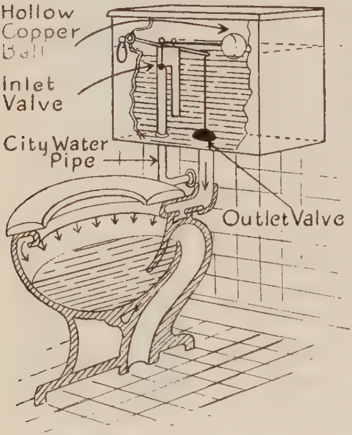


Fig. 115. A Flush-Tank and Bowl

There are many kinds of flush-tanks. The one pictured here is a common variety, but all kinds work on the same principle.

Exercise 11. Make a drawing of the flush-tank showing the position of the various parts when the float-ball is down. If you can remove the lid of the flush-tank in your house, do so. Operate the lever or chain and observe what happens inside the tank.

Every building should have a drainage system. Another problem in the control of water in the house is the removal of the waste water. This is a matter which is of importance, not only from the standpoint of convenience, but also from that of health. Every house which is supplied with city water must also have a drainage system. Figure 116 shows the plumbing in a modern residence. You will notice that below each bath tub or sink there is a curve in the pipe. This curve, or *trap*, is always full of water and prevents sewer gas, which is both unpleasant and dangerous, from entering the house. The soil pipe, which extends above the house, prevents these gases from accumulating in the drainage system. Examine Figure 116 and locate the traps and soil pipe. Sometimes the traps get filled with grease or other materials and the water will not flow out. If concentrated lye or boiling water is frequently poured into the drain, this grease will not accumulate, and the water will not be blocked. In case solids get lodged in this trap, another remedy is used. Such a condition may be remedied by unscrewing a small plug which is usually placed in the lower bend of the trap, taking out the materials, and replacing the plug.

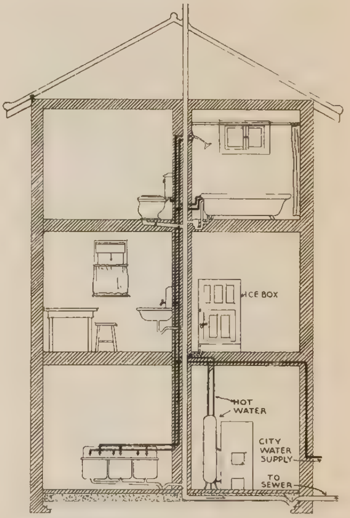


Fig. 116. Plumbing in a Modern Residence

Note that the water-supply system has no connection with the sewage system.

Exercise 12. Examine the drainage system of your house. Make a drawing of the different kinds of traps used. Make a drawing of the water system in your house, showing the supply system and the drainage system.

PROBLEM 5: HOW IS HOT WATER SUPPLIED IN THE HOME?

A very common appliance for obtaining hot water is the *storage tank* connected with the kitchen range (Figure 117). The storage tank is supplied from the water-supply system, the water entering at the top. A pipe connects the tank with a coil of pipes or a *water-front* in the stove. Another pipe carries the hot water back to the storage tank.

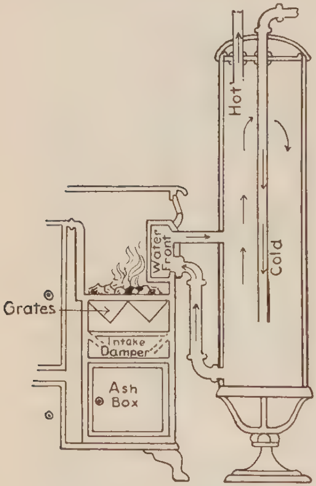


Fig. 117. Hot-Water Storage Tank Connected with Kitchen Range

Experiment 24: How is the water in the storage tank heated?

(*a*) Obtain a straight glass tubing three-eighths of an inch in diameter and about three feet long. Bend as shown in Figure 118. (Straight tubes connected with rubber tubing can be used if desired.) Obtain a bottle with the bottom cut off or a straight lamp chimney, fit a two-holed cork in one end, and arrange the apparatus as shown. Drop some sawdust thoroughly soaked in water into the tubes and also into the bottle. Fill the apparatus with water.

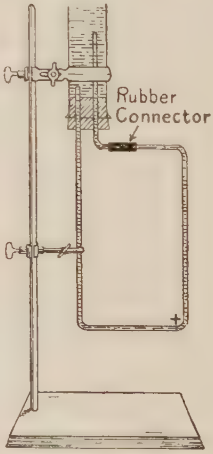
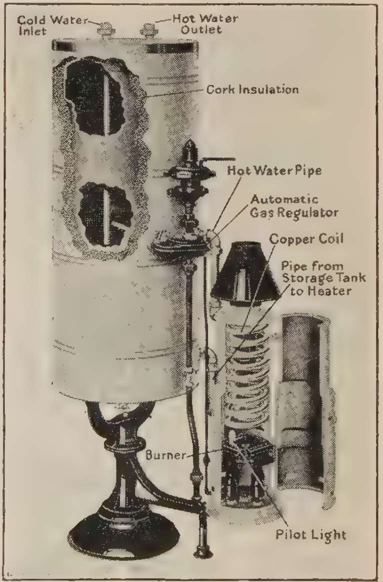


Fig. 118. How Water Circulates

(*b*) Heat one tube of the apparatus by moving a small flame rapidly up and down the lower part of the tube at the corner marked +. Observe that the height of the water in the bottle is increased. Why? Note the movement of the water as shown by the sawdust particles. Does the cold water move up or down? In which direction does the warm water move?

Exercise 13. From the results obtained in Experiment 24 explain how the water is heated in the tank shown in Figure 117. When a hot-water faucet is opened, what happens in the tank?

In many buildings heating coils are placed in the fire-boxes of furnaces to furnish hot water. These coils may or may not be connected with a storage tank. If they are not connected with a tank, the hot water is soon exhausted when the faucet is opened, because the water may flow through the pipes faster than it can be heated. This type of hot-water supply has the same disadvantage as the kitchen-range water supply, namely, that hot water can be furnished only when a fire is burning in the heater.



Courtesy Ruud Manufacturing Co

Fig. 119. An Automatic Gas Water-Heater

The most satisfactory hot-water supply is obtained in houses which are connected with artificial or natural gas. The heater usually consists of a coil of copper water-pipes surrounded by an iron jacket, and connected with a hot-water tank (Figure 119). The heat from the flame passes upward and circulates around the water-pipes, which offer a large amount of surface to the flame, thus heating the water very quickly. The gas is burned inside of the jacket at the base of the heating coils, and the size of the flame is controlled automatically. At the bottom of the storage tank is a copper tube, which expands when heated and contracts when cooled. This copper tube is connected with the gas supply. When the water is cold, the tube contracts

and opens the gas valve. As the water is heated, the tube expands and closes the valve. A small pilot-light is always left burning, and the heater needs no attention. With the gas heater hot water is always available in any quantity, and the amount of fuel burned depends upon the amount of water used.

Exercise 14. Why is hot water always available when a gas water-heater is used?

Exercise 15. State the advantages and disadvantages of each method of heating water.

PROBLEM 6: HOW IS OUR WATER SUPPLY KEPT PURE?

You have probably heard the old saying, "An ounce of prevention is worth a pound of cure." In obtaining a water

Fig. 120. (See Exercise 16.)

Fig. 121. (See Exercise 16.)

supply this should be the "Golden Rule," for our water supply is easily contaminated with disease germs unless the proper precautions are taken. There are three main sources of pollution: (1) wastes from human beings and animals, (2) decaying plant and animal life, and (3) garbage. Of the three, wastes from human beings and animals are the most dangerous because they may contain germs of at least five diseases: typhoid fever, cholera, diarrhea, enteritis, and dysentery.

Fig. 122. (See Exercise 16.)

Shallow wells which are improperly constructed or located are common sources of danger.

Exercise 16. Figures 120, 121, and 122 show three possible locations of a well in regard to the surface drainage and the underground drainage. Which of the three locations of the well is the most desirable? Why?

In houses where the well is used as a source of water and there is no sewage system, it is necessary to construct a *cesspool* or *septic tank* to dispose of the sewage. The cesspool is merely a hole in the ground, ten or twelve feet deep and four or five feet in diameter. This is usually lined with stones. It is intended that the solid materials will be broken up by the bacteria and form liquids which together with the liquid parts of the sewage will soak into the ground. At the best this is a very insanitary method of sewage disposal, and if it is used, the cesspool should be at least fifty feet from the well, and its drainage should be away from the water supply. The septic tank is made of concrete (Figure 123). In this device the solid materials are completely changed to liquid, which passes from one container to another, thus insuring a complete decomposition by the bacteria before it drains into the soil.

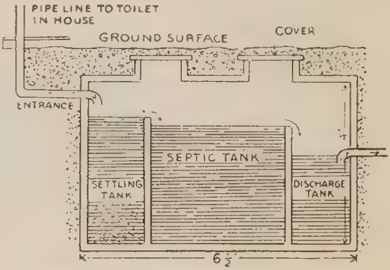


Fig. 123. A Small Septic Tank

The septic tank is located some distance away from the house.

Exercise 17. Why is the septic tank more sanitary than the cesspool for sewage disposal?

It is a very difficult problem to safeguard the water supply of a city, because in most instances the source of supply is surface water. Cities which obtain their water from rivers and lakes must prevent, if possible, the discharge of sewage and wastes into the water within certain distances from the

city. Most cities obtain the water upstream from where they empty their sewage, but they do not always consider the danger to other communities located downstream.

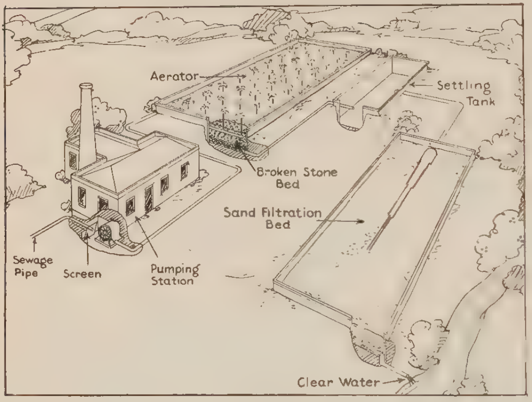


Fig. 124. Sewage Disposal Plant of a Large City

The sewage is carried by huge pipes to the pumping station. The liquid materials are then pumped to the aërator where they are sprayed into the air and filtered through the broken stone. From there they pass to the settling tank, and finally are filtered in the sand bed.

The purity of the water supply depends largely on the proper disposal of the sewage. A modern and scientific method of disposal is to collect the sewage into very large basins or septic tanks, where the sewage is partially broken down by bacteria, treated with a chemical, such as hypochlorite of lime, and then drained into the soil or into a stream. Another method is shown in Figure 124.

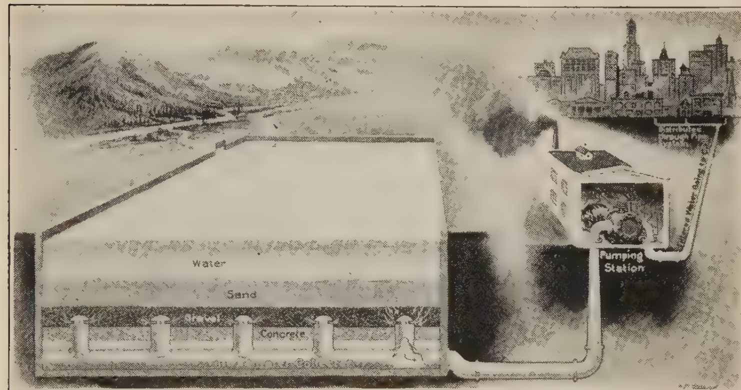
As a measure of precaution the water supply should be regularly tested. Most cities make daily or weekly tests of their water supply, and in case exceptionally large numbers of disease-producing bacteria are present, the water is treated chemically, and people are warned to boil the water before drinking it. The State Board of Health also maintains a laboratory, and an analysis of water is made free or at a small cost.

Exercise 18. Why is the problem of sewage disposal in a city much more complicated than in a rural home?

Exercise 19. How is your local water supply safeguarded against pollution?

PROBLEM 7: HOW IS WATER PURIFIED?

If you live in a city which obtains its water supply from a river, you have perhaps wondered how the muddy water in



From Compton's Pictured Encyclopedia. Courtesy F. E. Compton & Co., Publishers.

Fig. 125. A Sand Water-Filter for a Large City

The layers of sand and gravel are made very thick so that the water trickles through very slowly.

the river can be made fit for drinking. The water in the river may contain all sorts of impurities, such as decayed animal and vegetable matter, sewage from towns along the banks, and disease-producing germs. Yet this water may be made fairly safe.

Perhaps the commonest method of removing impurities from water is *filtration.*

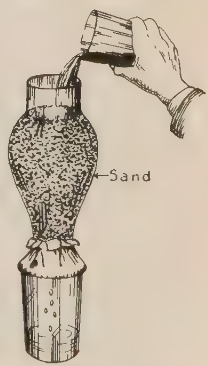


Fig. 126
Filtration Apparatus

Experiment 25: How is water made pure by filtration?

Tie a cloth over the bottom of a lamp chimney and support it on a tumbler (Figure 126). Pour in some coarse sand to make a layer about two inches thick. Now pour in fine sand within an inch of the top. Make a mixture of muddy water and pour it in at the top of the chimney. What change takes place in the water?

Figure 125 shows a type of sand filter commonly used by many cities. Analysis of the water shows that soil particles and practically all disease-producing germs are removed by this process. Figures 127 and 128 show a filter which may be used in the home. In this filter the water is forced by the pressure in the water system through a porous porcelain tube which removes all impurities.

Standard Filter Co.

Fig. 127. A Filter for Home Use

The larger of the two tanks is a cooler and storage tank. Figure 128 shows a sectional view of the smaller tank, which contains the filter proper.

Another practical method of purifying water is storing it in a reservoir for several weeks. Suspended impurities, such as soil particles, slowly settle to the bottom and the water becomes clear (Figure 129). This does not mean that the water is yet pure, for the clearest water may contain millions of disease germs. But because the reservoir is uncovered, the germs are destroyed by the sunlight and by the oxygen dissolved in the water (Figure 130). Certain bacteria in the water also help to decompose some of the decaying material and to destroy some of the disease producing germs.

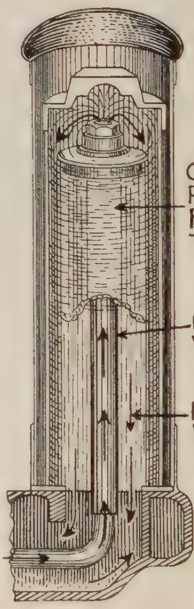


Fig. 128. Sectional View of a Home Water-Filter

From this tank, shown at the right in Figure 127, the filtered water passes into the tank on the left, where it is stored and cooled.

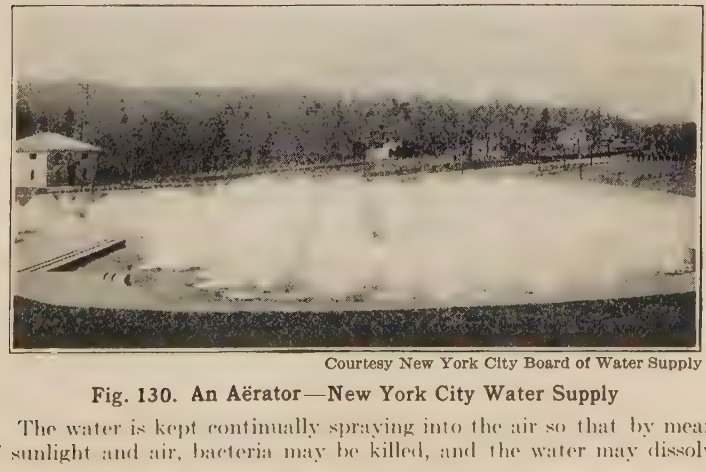
In cities where the water as it comes from its original source is very muddy, it is necessary to purify it by another

method. Experiment 26 on page 138 will show you how this may be done.

Courtesy St. Louis Department of Public Utilities

Fig. 129. Cleaning a Settling Basin

This is one of the settling basins shown in Figure 97, after it has been in use for three months. Note the enormous amount of mud which has settled from the water and which the workmen are removing. In some places it seems to be ten or twelve feet in depth.



Courtesy New York City Board of Water Supply

Fig. 130. An Aërator—New York City Water Supply

The water is kept continually spraying into the air so that by means of sunlight and air, bacteria may be killed, and the water may dissolve more oxygen.

Experiment 26: How can muddy water be cleared?

Fill two small bottles with muddy water. Put a small quantity of alum solution in one bottle. Allow the two bottles to stand, observing the changes in appearance of the water in each bottle. After twenty-four hours have passed, note which bottle contains the clearer water.

The alum causes the minute particles of soil to come together and form larger particles. These larger particles sink to the bottom of the container. As they sink, they carry with them many of the bacteria present. In large cities the water is treated with alum and later filtered or treated with chemicals.

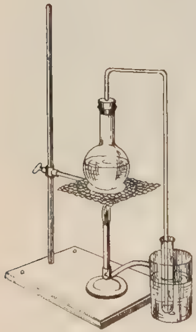


Fig. 131. Distillation Apparatus

In cases where the water supply is badly contaminated, some other method of killing the disease-producing germs must be practiced. In some cities this is done by putting a small amount of *chlorine* gas, or bleaching powder, into the water. The chlorine gas or bleaching powder kills the germs. These materials are objectionable in that they give the water a peculiar taste if they are used in large quantity. Another way of making sure that the water is free from disease-producing germs is to boil it for half an hour.

In order completely to remove the germs as well as all other impurities water is *distilled*.

Experiment 27: How does distillation remove impurities from water?

Construct an apparatus as shown in Figure 131. Fill the flask one-fourth full of muddy water containing two or three teaspoonfuls of salt or sugar, and some ink. Heat the flask. When the water commences to boil, reduce the size of the flame so that it will boil slowly. Note the drops of water which collect in the delivery tube and in the test tube. Examine the water in the test tube. Taste it. Is it pure?

Exercise 20. What two changes take place when water is distilled? (See pages 38 and 47.) In Experiment 27 why are the impurities left in the flask? Why does the water have a "flat taste"?

Exercise 21. Which of the methods or combination of methods listed in Problem 7 is the most practical for purifying water supplies of large cities? For purifying home water supplies?

Review Exercise on Unit V. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit V and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT IV

1. Why is it often necessary to "prime" a pump, that is, pour a little water in the cylinder, when it has not been used for some time?

2. In Unit II you learned that the air pressure is approximately 15 pounds per square inch. If a cubic inch of water weighs .0362 pound, how many feet will water rise in a pipe below the piston of the pump from which all of the air is removed?

3. In a driven well which is very deep the piston must be placed deep in the ground. Why? Make a drawing showing the location of the different parts of a pump in a deep well, and explain how the water is brought to the surface of the ground.

4. Why are fire engines which use double-acting force pumps usually equipped with an air dome?

5. Make a list of the possible causes of a leaky faucet, and state how you would remedy them.

6. What parts of the flush-tank are most likely to get out of order?

7. Why do some wells and springs go dry at certain seasons?

8. Mountain streams usually furnish a pure water supply. Why?

9. Why is cistern water sometimes dangerous to drink? What impurities may it contain?

10. How can the crew of a ship prepare fresh water out of sea water? How does nature do it?

11. A housewife finds that water flows with greater force from the faucet at midnight than at midday. Explain.

12. Explain why water flows more rapidly from a faucet on the first floor of a house than from one on the third floor.

UNIT V

KEEPING IN GOOD PHYSICAL CONDITION

Preliminary Exercise

Write a composition entitled "Keeping Physically Fit." Tell all you know about your own body and how you should take care of it.

THE STORY OF UNIT V

In whatever climate and under whatever weather conditions we live, our first problem is that of keeping well, for both our efficiency and comfort depend upon our health. It is said that a Chinaman pays his doctor to keep him well, and that the doctor's pay stops when he gets sick. Whether or not this is true, it is not a bad idea, for an ounce of prevention in matters of health is worth a pound of cure.

Our present indoor life makes the problem of keeping well more complicated than it was in the days when man spent most of his time outdoors. Buildings and houses must be properly heated and ventilated in order to assist in keeping the human machine in its best condition. A large proportion of our population do no hard physical work. This makes it necessary for them to obtain their exercise after work hours. Competition in the business world has so increased that man must keep incessantly "on the job" in order to succeed. This speeding up of life in the modern world has resulted in a greater strain on the human body and has required us to pay careful attention to our bodily needs.

The human body consists of many systems which work together harmoniously (Figures 74, 132, and 136). Each has a special work to do. For example, the body is supported by a framework of bones, known as the *bony system*. Attached to the bones, which make up the skeleton, are *muscles*, com-

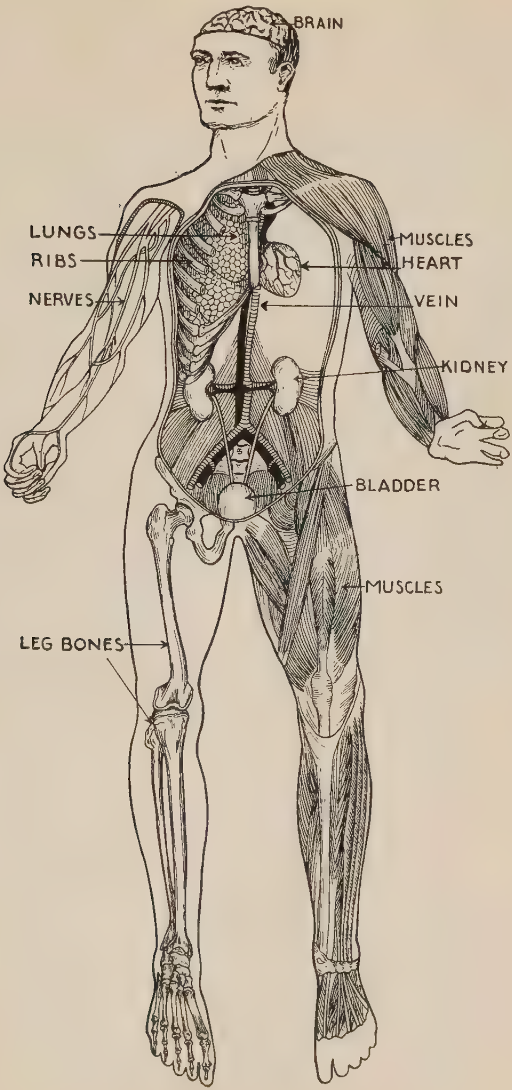


Fig. 132. Systems of the Human Body

posing the *muscular system*, which enables us to move our arms, legs, fingers, head, and ribs. In addition to these parts of the body whose movements we can see, there are other internal parts such as the stomach, intestines, and heart, which also are moved by the action of muscles. The duty of the *digestive system*, which consists of the teeth, stomach, and intestines, is to prepare the food so it may be used by the body. A special system is required, however, to carry the food to the different parts of the body. This is the duty of the *circulatory system*, which consists of the heart, blood vessels, and blood. Oxygen is necessary to obtain energy from the food. The *respiratory system*, which consists of the lungs and air passages, secures this oxygen from the air and also throws off certain wastes which are formed when the foods combine with oxygen. Here again the circulatory system must carry the oxygen to the cells and the wastes away from them.

Other wastes from the foods and broken-down cells are eliminated by the *excretory system*, which includes the intestines, kidneys, liver, and skin. You can see that every system of the body must be in good working order, because every part of the body is dependent upon every other part. Of course, in a complex machine of this kind there must be some controlling force which will direct the activities of the different parts. This is the work of the brain, spinal cord, and nerves, which make up the *nervous system*.

In the different systems mentioned above are many *organs*, each of which has some special part to play in the body. For example, the stomach and intestines are organs, each of which has a particular use in the digestive process. The organs themselves are also made of different kinds of material called *tissues*. Muscles, bones, glands, nerves, and tendons are all tissues, and each has a definite work, or *function*, to perform.

If the tissues are examined under a high-power microscope, it is found that they are composed of very small parts called cells (Figure 133). The cell is the smallest unit into which living material can be divided, and for this reason it is

called the *structural unit* of living matter. The cells might be compared to the grains of sugar which make up a cake of loaf sugar. They differ, however, from the grains of sugar

Fig. 133. Cells of the Human Body

(*a*) Muscle cell of the stomach; (*b*) Nerve cell; (*c*) Epithelial cells from tongue; (*d*) Cartilage cell; (*e*) Goblet cell from intestines; (*f*) Ciliated cells from bronchial tube.

in that there are many different kinds of cells in the body, each of which has a special work to do.

To keep the cells, tissues, organs, and systems in good condition so that there will be good teamwork is the problem of keeping well. Three kinds of material, each in the proper amount, are essential to one's physical well-being—pure food, pure water, and pure air. To understand how these materials are used by the body and how to take care of the various parts of the body which prepare these materials for use, makes for proper living.

Two other necessities which are intimately connected with healthy living are proper exercise and rest. Exercise helps get rid of undesirable wastes in the body and also assists the various organs of the body in their work. Rest and sleep give the body time to rebuild and repair the cells which are broken down.

Keeping physically fit is thus a matter which is largely within the control of every individual. It consists in practicing healthful habits of living. To know what these habits are and the reasons for them, and then to practice them day by day until they become a part of us will enable us to live longer and more comfortably.

PROBLEM 1: WHAT BECOMES OF THE FOOD YOU EAT?

Digestion changes food to a liquid form. You already know that the food you eat is changed into body material or is used for supplying energy. Since the food must be transported to all parts of the body by the blood, it must pass through the walls of the digestive organs to the blood. This can take place only if the foods are in the form of a liquid. Since most of the food we eat is solid, it is necessary to change it to the liquid state. *Digestion* has for its purpose the changing of foods from a solid to a liquid state so that they may pass through the walls of the digestive organs and be carried to the different parts of the body.

Experiment 28: How can solids be changed to liquids?

(*a*) Add a pinch of salt or sugar to a test tube half full of water, and shake. Hold the test tube up to the light. What has become of the solid? When a solid mixes with a liquid so that the particles are no longer visible, the solid is said to be in *solution;* that is, the solid has *dissolved.*

(*b*) Drop a small piece of limestone or marble about the size of a pea into a little water and shake it. Does it dissolve? Add 5 c. c. of hydrochloric acid to the water. Notice the small bubbles of carbon-dioxide gas which are formed. Allow it to stand until the next day. What finally becomes of the limestone?

From the first part of the experiment you see that sugar or salt will dissolve if it is placed in water. There are many materials which dissolve in this manner. Not all materials, however, will dissolve in water. Limestone, for example, is not *soluble* in water. One might think that the limestone dissolved in the acid, but this is not the case. The acid acted upon the limestone and produced a *chemical change* in it. When a material is changed chemically, it becomes a new material. The hydrochloric acid combined with the limestone and produced carbon-dioxide gas, which passed off into the air and left a new substance called calcium chloride. The calcium chloride is soluble in water; so it dissolved and disappeared. Digestion is accomplished in our body in a similar way. Various digestive fluids are found in the digestive organs. These fluids dissolve our foods or change them into new materials which will dissolve.

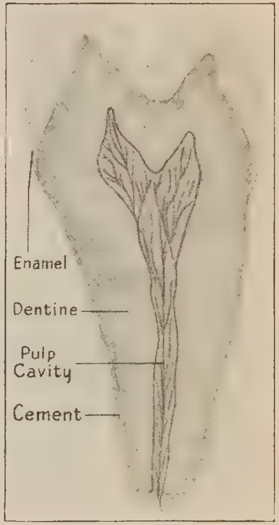


Fig. 134. Longitudinal Section of a Tooth

The digestive process begins in the mouth. The *teeth* perform the first act in the process of digestion. They are so constructed that they can tear, grind, and cut the food. When the foods are ground up, they may be easily penetrated by the digestive fluids of the mouth, stomach, and intestines. In order that the food be thoroughly *masticated*, one must eat slowly. This has two values: it reduces the food to small bits, and it also stimulates the flow of the digestive fluids. Both of these actions result in more thorough digestion.

Figure 134 shows a longitudinal, or lengthwise, section of a tooth with its parts labeled. When the outside enamel, which is very hard, is worn off, the softer parts on the inside soon

decay. This decay is caused by the action of certain bacteria which form an acid from the bits of food left between the teeth. To prevent this, it is necessary to clean the teeth thoroughly after each meal. It is well worth while to have a dentist examine the teeth once or twice a year to detect spots which are decaying and which may be filled before they are large enough to cause pain or loss of the tooth. The teeth are necessary for proper mastication of food, and as such they should be carefully guarded against decay.

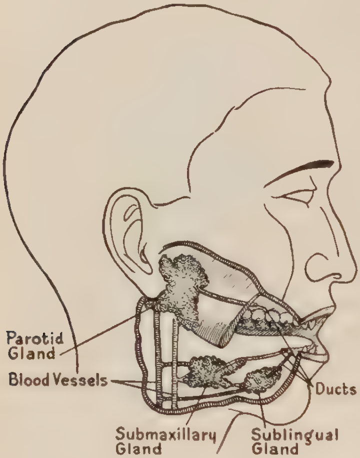


Fig. 135. The Salivary Glands

There are three pairs of salivary glands: the parotid glands lie under each ear, the submaxillary glands lie below the two halves of the lower jaw, and the sublingual glands lie under the tongue.

Exercise 1. Enumerate several foolish practices which people do to or with their teeth, such as picking them with a pin, etc. After each tell why it is a foolish practice.

During mastication the food is mixed with a fluid called *saliva*. This is manufactured in the *salivary glands* (Figure 135) and is forced into the mouth through *ducts*. It has two uses: first, it moistens dry foods, like crackers, so that they may be easily swallowed; second, it digests the starch. You remember that foods like potatoes contain large quantities of starch. This starch must be digested before it can pass through the walls of the intestines. This digestion is partially accomplished by the saliva.

Experiment 29: What effect does saliva have upon starch?

(*a*) Drop a small piece of starch about half the size of a pea in a test tube half full of water. Shake the tube vigorously. Does

it dissolve? Test the contents of the tube for sugar (Experiment 16, page 88).

(*b*) Add some saliva to a second test tube containing starch and water. Place the tube in a beaker of water, and keep the temperature of the water at 100°F. for twenty minutes. Test the contents of the tube for sugar. What effect does the saliva have upon the starch?

Proteins are digested in the stomach. After the food is thoroughly masticated and moistened with saliva, it passes back through the mouth into the *esophagus*, which opens into the *stomach* (Figure 136). The stomach (Figure 137) is a pear-shaped muscular organ with a capacity of from three to five pints. Its inside wall is covered with a thin *membrane* which contains the *gastric glands*. The gastric glands manufacture *gastric juice*, which aids in the digestion of proteins.

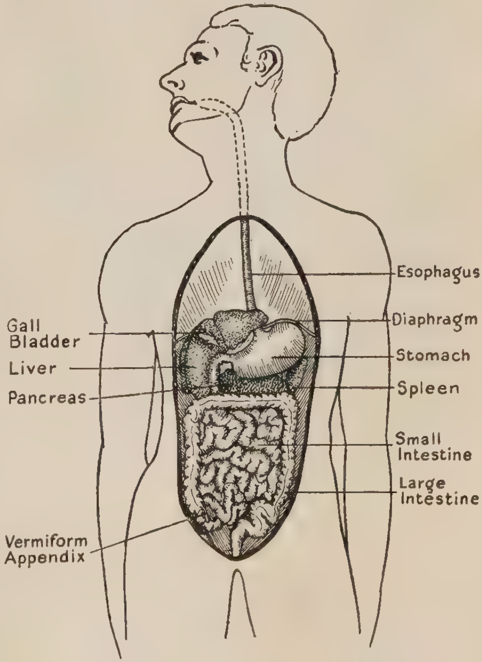


Fig. 136. The Digestive System in Man

Note the position of the various organs.

Experiment 30: What effect does gastric juice have upon proteins?

(*a*) Artificial gastric juice can be prepared by mixing one-half gram of pepsin (which can be obtained at any drug store) with 2 c. c. of hydrochloric acid and 50 c. c. of water.

(*b*) Boil an egg in some water. Cut the white of the egg into small bits, or press it through a wire gauze. Add a small portion of this to the artificial gastric juice, and keep the temperature at about 100°F. for two or three hours. What effect does the gastric juice have upon the egg?

(*c*) Repeat (*b*), using the same amount of egg and artificial gastric juice, and shake the test tube often. Compare the results obtained with those obtained in part (*b*). What effect does shaking have upon the rate of digestion?

The action of the gastric juice on the foods is assisted by the muscles of the stomach. When these muscles *contract*, they become shorter and thicker; when they *relax*, they become longer and narrower. By alternately contracting and relaxing they keep the contents of the stomach in motion and thus mix the foods with the gastric juice.

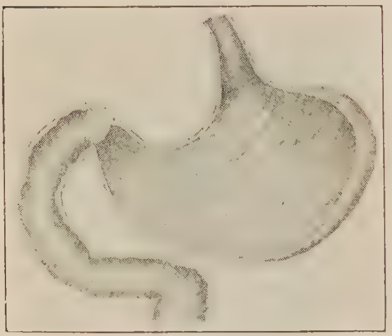


Fig. 137. The Stomach

Observe the folds of muscles on the inside walls. Turn to Figure 136 to see where this organ is located.

Digestion is completed in the intestines. The contents of the stomach are emptied into the small intestine, which is a coiled tube about twenty-two feet long. Here the food is further mixed with *intestinal juice*, with *bile* which comes from the *liver*, and with *pancreatic juice*, which is manufactured by the *pancreas* (Figure 136). These juices complete the action of dissolving digestible parts of the food. Most of the food is absorbed through the walls of the small intestine by the blood (Figure 138).

Some of the food, both digested and undigested, together with the digestive juices, passes into the large intestine (Figure 136). Dissolved foods are absorbed here, while the undigested food is gathered and passed out of the body, or *excreted*.

The bowels must move regularly. It is most important to our health that undigested food be excreted. (See page 91.) The lower part of the intestines contains many bacteria, which change some of these waste materials into poisons. These poisons are taken up by the blood and produce a bad effect on the whole body. They frequently cause dull, sick headaches. In order to prevent this, the intestines should be evacuated at least once a day. In case this does not happen naturally, drink a glass of water when you retire at night, and also when you get up in the morning; eat more fruit, vegetables, and coarse foods, such as bran bread, and in most cases relief will be obtained.

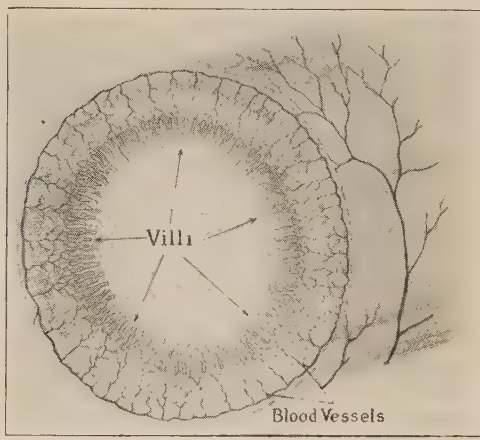


Fig. 138. A Cross-Section of the Small Intestine
The villi are small projections in the intestine, which absorb the digested food.

Exercise 2. Write a story telling the experiences of a piece of bread from the time you eat it until it is changed into part of your body.

PROBLEM 2: WHAT BECOMES OF THE AIR YOU BREATHE?

The air is a mixture of colorless gases. It is hard to realize that material may be invisible. Yet you live in an ocean of air composed of colorless gases. Chemists have very accurately determined what these gases are and the quantity of each, as shown by the table on the next page.

TABLE VI: APPROXIMATE COMPOSITION OF AIR

Oxygen	21%	Carbon dioxide	.04%
Nitrogen	78%	Water vapor	Varying amounts
Argon	.94%		

Unfortunately the air you breathe is not always pure. It may contain smoke, dust particles, or disease germs. These dust particles may be seen by means of a simple experiment.

Experiment 31: How can the dust particles in the air be made visible?

Select a room which has windows on the south. Choose a day when the sun is very bright and pull down the shades so that the room will be quite dark. Now pull one of the shades aside so that a thin streak of sunlight can enter the room. Observe the path of the sunlight through the darkened room. What do you see?

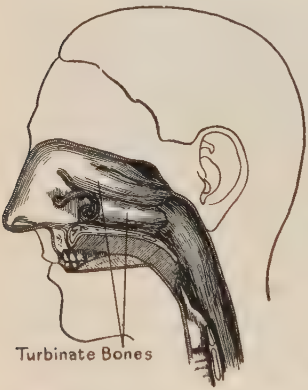


Fig. 139. The Turbinate Bones in the Nose

The air passes around the turbinate bones and therefore comes in contact with a large surface of moist membrane.

If these dust particles enter the lungs, they may lodge in the lung tissues and cause serious trouble. Of course, one cannot always choose the kind of air he breathes, but he can, to some extent, prevent the entrance of these particles into his lungs if he breathes properly.

One should always breathe through the nose. There are two entrances through which air can get into the body: the mouth and the nose. The proper way to breathe is through the nose. Inside the nose are many fine hairs which act as a sieve in sifting out some of the larger dust particles. The actual surface of the inner nose is very great because of the projection of the *turbinate bones* (Figure 139) which extend into the passage. These bones are covered with a thin, moist *mucous membrane*. As the air passes over this membrane, dust particles and germs are caught by the sticky surface. This membrane

also contains many blood vessels, and the heat which escapes from them serves to warm the air before its entrance into the

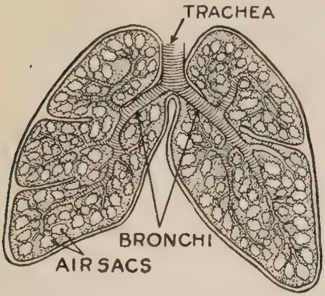


Fig. 140. The Lungs

The branches of the bronchi end in tiny air sacs. These air sacs are surrounded by many small blood vessels.

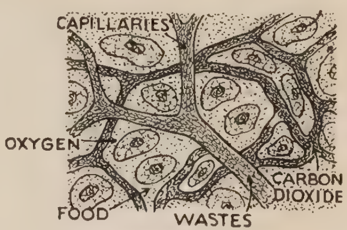


Fig. 141. Exchange of Food and Waste Products in the Body

The blood vessels divide into tiny *capillaries.* The food and oxygen pass through the walls of the capillaries to the cells, and the waste passes from the cells into the blood.

body. The necessity of always breathing through the nose is apparent. Mouth breathing not only looks bad, but it permits the impurities in the air to enter the lungs, thus increasing the likelihood of disease.

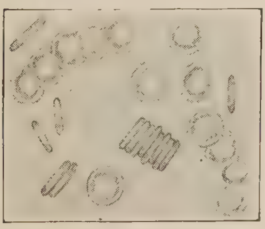


Fig. 142. Red Blood Corpuscles

A drop of blood contains about 50,000,000 corpuscles.

The oxygen enters the blood in the lungs. From the nose, the air passes into the *pharynx* (Figure 74, page 85), then down into the windpipe, or *trachea* (Figure 140). The trachea divides into two branches, the *bronchi*, when it reaches the lungs. The bronchi divide and sub-divide until the branches are extremely small. These air passages are lined with mucous membrane containing thousands of tiny blood vessels. Some of the oxygen in the air passes through the membrane into the blood vessels, and combines with the *red corpuscles* (Figure 142). These corpuscles carry the oxygen to all parts of the body, where it is gradually given up to the cells (Figure 141). In exchange for the oxygen, the cells give

up *carbon dioxide*, which is a waste material formed when the food combines with oxygen.

If you examine the blood vessels in your arm, you notice that the blood appears blue. If, however, one of these blood vessels is cut, the blood which you see is red. Why is this true? To understand this you must know more about the circulation of the blood. While the blood is in the lungs, some of the material in the red corpuscles combines with the oxygen and produces a red substance which gives the blood its color. The blood then flows back to the heart, where it is pumped all over the body. As the corpuscles give up their oxygen, the color of the blood changes to blue. The blood vessels which you see through the skin contain blood which has given up its oxygen. This blood goes back to the lungs, where it gives up its carbon dioxide, obtains a fresh supply of oxygen, and is again pumped over the body.

Exercise 3. Why is "blue" blood never seen outside the body?

That carbon dioxide is given back to the air in the lungs, you can see by the following experiment.

Experiment 32: How does the air which is expelled from the lungs differ from the air which enters the lungs?

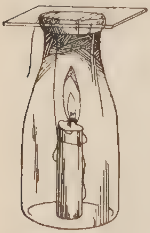


Fig. 143. Apparatus for Experiment 32

(*a*) Take the temperature of the air in the room; then breathe on the thermometer. Result?

(*b*) Blow your breath against a cold windowpane. What do you see?

(*c*) Place a lighted candle in a wide-mouthed bottle (Figure 143), cover with a glass plate, and note how long it burns. Now fill the bottle with water and arrange it as shown in Figure 144. Blow into it through the rubber tube until it is full of expired air. Place a glass plate under the mouth of the bottle and then invert it so that the mouth of the bottle is up. Light a candle, slide the glass plate to one side, and lower the candle into the bottle, immediately covering the mouth of the bottle with a glass plate. Note how long the candle burns. Compare the time it burns in expired

air with the time it burns in ordinary air. (Remember that burning is caused by oxygen.) How do you account for the results?

(*d*) Heat a small piece of charcoal in a flame until it glows red. Then quickly drop it into a dry bottle and cover it with a glass plate. Wait until the charcoal "goes out," and then pour a little limewater into the bottle and re-cover with the glass plate. Shake the bottle vigorously for a minute or two and note that the limewater turns milky. This is the chemist's test for carbon dioxide. Pour a little limewater into a bottle of ordinary air and shake it. Does it turn milky? What does this show? Now insert a glass tube into the limewater and blow through it for several minutes. How do you account for the change in the limewater?

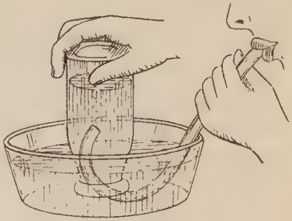


Fig. 144. Apparatus for Experiment 32

Your experiment shows you that expired air is different from ordinary air in four respects: (1) its temperature is higher; (2) it contains more water vapor; (3) it contains less oxygen; and (4) it contains more carbon dioxide. Breathing, therefore, is of value not only in furnishing the cells with oxygen but also in reducing the body temperature and in getting rid of wastes.

Deep breathing is necessary. Since breathing is such an important process, it is necessary that all parts of the breathing mechanism be kept in good order. Probably one of the most important health habits which one can acquire is the habit of deep breathing through the nose. If deep breathing is not practiced, part of the lung surface is not used. As a consequence the unused parts are readily attacked by disease germs. To prevent shallow breathing one must stand and sit erect. The clothing around the chest and waist should be loose enough so that it will not interfere with the elevation of the ribs, which takes place when air enters the body. Plenty of exercise, which results in deep breathing, insures that all parts of the lung surface are in use.

Proper ventilation secures fresh air. Another important condition in keeping the breathing mechanism in good order is proper *ventilation* of our buildings. Ventilation accomplishes two results: it brings in fresh air, and gets rid of the air which has been changed by breathing. When possible, the air should come into the room through several small openings rather than one large opening. That is, in a room having several windows, some should be raised slightly at the bottom and others lowered slightly from the top. This will prevent strong drafts. Especial attention should be given to sleeping-rooms.

Experiment 33: How may you use the windows in a room to secure the best ventilation?

(*a*) Obtain a wooden box about 1 foot by 6 inches by 6 inches. Remove one side of the box. Bore two small holes about one-half inch in diameter in each end of the box. One hole should be at the bottom and one at the top, as shown in Figure 145. Each hole should then be stoppered with a cork.

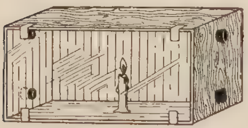


Fig. 145. Ventilation Box Apparatus

Gummed labels may be used to hold the glass plate against the box.

(*b*) Remove the cork from one of the holes near the bottom of the box. Light a candle about three inches long, and place it in the center of the box. Place a glass plate securely against the open side of the box. Note how long the candle burns.

(*c*) Repeat (*b*), removing the cork from different holes until you find the best way to ventilate the box. You can determine this by noting the length of time the candle burns and the size of the flame.

Exercise 4. Write out the following statements, filling in the blank spaces.

The air which enters the body has the following impurities which are removed in the nose: (*a*) dust......... (*b*) .... It also contains...................., which is necessary for the burning of the food in the body. When the air passes into the lungs, the blood takes....................from it and gives back.................................... The temperature of the air from the lungs is..................than that of the outside air, and there is also more ....present.

Exercise 5. Complete the following statement, using the best answer:

Deep breathing is necessary because:

1. It enables us to exercise more vigorously. 2. It makes us breathe faster. 3. It develops our lungs. 4. It prevents disease.

Exercise 6. At least 30 cubic feet of air per person should be furnished in a room every minute. How many cubic feet of air are necessary in your school room every hour? How many times an hour should the air in the room be changed completely?

PROBLEM 3: WHY IS PLENTY OF EXERCISE AND REST NECESSARY?

Exercise of the proper kind has a beneficial effect upon every process in the human body. For this reason everyone should take some exercise every day of his life. It is better to exercise out-of-doors, because there is a more plentiful supply of fresh air, and because of the beneficial effect of sunshine.

Hard mental work should be followed by light exercise. Exercise is particularly necessary for the brain-worker. When one studies hard, an increased supply of blood is sent to the brain, which diminishes the quantity in the stomach, muscles, and other parts of the body. Exercise sends the blood to these parts of the body and thus restores the circulation of the body to normal. It is therefore desirable to follow hard study with some light exercise.

Experiment 34: What effect does exercise have upon the rate at which the heart beats?

(*a*) When your heart pumps blood into the arteries, a wave of blood is sent through them. In order to count the number of heartbeats per minute it is only necessary to find a place where there is an artery close to the surface of the body. This can be found in the wrist or behind the ear. After you have been sitting still for some time, find out how many times your heart beats per minute by taking your *pulse*.

(*b*) Take some light exercise and again count your pulse. How do the results obtained while you are quiet differ from those taken immediately after exercise?

When one exercises, the heart beats faster and the blood circulates more rapidly. More oxygen and food are thus carried to the cells, and the wastes of the cells are removed more rapidly. These changes which take place as the result of exercise keep the whole circulatory system in good working order.

Exercise helps us get rid of waste materials. Everyone marvels at the endurance of runners in long-distance or marathon races. This endurance is, of course, the result of long continued training. With exercise, the rate of breathing increases, and by breathing correctly, we can use our lungs to their fullest capacity. This enables us to obtain a sufficient supply of oxygen to meet the increased rate of blood flow and also to get rid of the wastes formed as a result of the rapid burning of food and the destruction of body cells.

Another very important result of exercise is the increase in the amount of *perspiration* poured on the skin. Perspiration contains some of the body wastes, and thus the skin is one of the important organs of excretion. The *kidneys* and *liver* are also organs of excretion, and they are frequently overworked, especially if we eat large quantities of protein food. (See page 91.) Exercise, by increasing the amount of perspiration poured on the skin, thus helps the kidneys and liver in removing body wastes.

Rest and sleep are also necessary to keep the organs of the body in good condition. Long-continued brain or muscular work makes us feel tired. During work of this kind the cells are broken down and need rest or sleep, which will give them time to repair themselves. It is frequently restful to change the kind of work being done, as this calls into play the action of different muscle and nerve cells, thus permitting the blood to carry away the waste materials which have accumulated and allowing the overworked cells to rest. There is, however, no substitute for rest and sleep.

Exercise 7. Write a paragraph comparing the effect of exercise and sleep upon different parts of the body.

PROBLEM 4: WHY SHOULD WE BATHE?

Bathing removes wastes from the skin. You are aware that when you exercise vigorously, perspiration from the sweat glands (Figure 146) is poured on the skin. This process, however, is going on continuously, even when you sleep. The sweat glands take waste materials from the blood and pour them out on the skin. Some of these waste materials are solid and some are liquid. In order to prevent the pores from clogging up with the accumulation of solid materials from the perspiration and dirt from the outside, it is necessary that you bathe frequently. Hot water and soap are required to cleanse the body thoroughly.

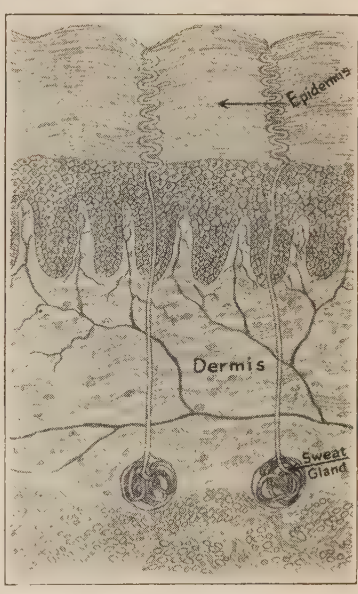


Fig. 146. Sweat Glands in the Skin

The skin is divided into two layers, the epidermis and the dermis. The sweat glands and blood vessels are in the dermis.

Bathing affects the circulatory system. In taking baths you must consider the effects of different kinds of baths upon the body. Hot baths open up the pores and increase the perspiration. They also cause the blood vessels near the skin to expand so that the body loses heat faster. When the skin is in this condition, one is very liable to "take cold." For this reason a hot bath should be followed by a very short cold bath. This will close the pores and drive the blood to the inner parts of the body. The cold bath should be followed immediately by a brisk rub with a coarse towel. This causes a second reaction of the blood vessels, and the skin again becomes pink, or "glows."

Bathing of the sort just described is very valuable, not only from the standpoint of cleanliness, but also from its effect upon the blood vessels. The blood vessels have circular muscles which regulate the flow of the blood (Figure 147). When the muscles of the blood vessels in the skin contract, the blood is sent to the inner parts of the body. When these muscles relax, the blood vessels become larger and more blood passes through the skin. In this way the body heat is automatically controlled, since, when a large quantity of blood flows through the skin, heat is lost, and when the blood is sent to the inner parts of the body, heat is saved. In order to keep the body temperature constant it is necessary that these changes in the size of the blood vessels take place very rapidly in response to a given change of outside temperature. Hot and cold baths give these muscles constant exercise and thus keep them in good condition.

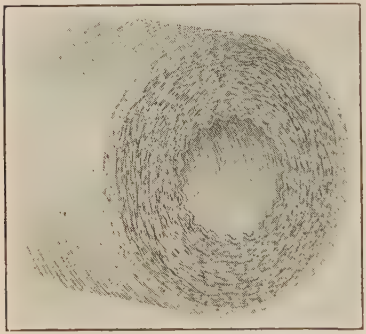


Fig. 147. Cross-Section of an Artery
Observe the thick muscular walls.

Baths should be taken at the proper time. The time for taking baths is also worthy of consideration. Baths should never be taken immediately after meals since they draw the blood away from the digestive organs and thus interfere with digestion. A hot shower bath followed by a shorter cold shower is an excellent way to start the day because of the good effects upon the circulatory and the nervous systems. During the hot summer months sponging off the body with cold or tepid water is a good way to secure sound sleep.

Exercise 8. Why should one always bathe after hard exercise?

Exercise 9. Explain how a hot bath immediately followed by a cold bath has nearly the same effect upon the body as hard exercise.

PROBLEM 5: WHY SHOULD WE NOT USE ALCOHOL AND TOBACCO?

Alcohol lowers the resistance of the body. Keeping in good physical condition results in making the body cells strong enough to resist the action of disease germs. It also keeps the different organs in the body in good working order. Perhaps the most serious effect of alcohol upon the body is the lowering of its resistance. This makes it easier for the germs to attack the body and cause serious or fatal illness. *Mortality* records, or death records, of life-insurance companies furnish information for determining the effect of alcohol upon the resistance of the body. Many studies of this kind have been made. One company reports that 40 per cent of the policy applicants are rejected for causes connected with the use of alcohol. Another company, which divides its policy-holders into "drinkers" and "non-drinkers," shows the following mortality in the two groups: Out of the number of deaths expected among the non-drinkers during a period of 40 years, 71.54 per cent died. Of those who drank, 94 per cent died. This gives clear evidence that the use of alcohol shortens one's span of life.

How does alcohol lower the resistance of the body? To answer this question we must examine its effect upon different parts of the body. Probably the most noticeable effect of alcohol is its action upon the blood vessels in the skin. A small amount of alcohol causes these blood vessels to enlarge, and hence the body loses heat rapidly. This loss of heat requires the body to oxidize more food to make good the loss. Thus the body is overworked. A second effect is this: Small quantities of alcohol have been found to increase the flow of the gastric juice, but this increase is always followed by a decrease in the flow after the stimulation has worn off; in time the gastric glands cease to work without the presence of alcohol or some other stimulant. A third effect of alcohol is its action upon the muscle cells of the heart. These cells may be changed to fat, and thus the heart, which is really a pump, cannot force

the blood through the body at the proper rate. This destruction of the vital cells and their replacement by fat take place in many parts of the body. It is, therefore, easy to understand how alcohol lowers the resistance of the human body.

Alcohol affects our daily work. Employers have recognized for years that men who are habitual users of alcohol are not so efficient in their work as men who do not use alcohol. Recognition of this fact has led many employers to draw up rules prohibiting the use of alcohol during work hours. Others have gone still further in refusing to employ men who use alcohol at any time or in any amount. This is particularly true of railroads, where the lives of thousands of people depend upon the clear-headedness of their employees.

Many experiments have been carried on to determine the effect of alcohol upon one's ability to work. One such experiment was carried on with a group of typesetters. The results showed that even one ounce of alcohol per day was sufficient to reduce by 10 per cent the amount of work done. Another experiment determined the effect of alcohol upon one's speed in responding to certain stimulations. The person sits at a table with his finger on a telegraph key. A light is flashed and he releases the key. The time between the signal and the release of the key is measured. This is called the *reaction time.* The experiment showed that the reaction time was decreased if the test was made immediately after the alcohol was taken, but if made some time afterwards, the reaction time rose much above normal. Reaction time is very important when a quick decision is needed, as, for example, in avoiding a collision with an automobile or in running machinery of any kind. Since alcohol finally results in increasing the reaction time, it is easily seen that it slows up one's rate of work.

Accuracy is very important in many lines of work. An experiment somewhat like the one previously reported indicates the effect of alcohol upon accuracy. The person is seated at a table with each hand placed on a telegraph key.

If a white light appears, he is to press one key, and if a red light appears, he is to press the other key. Tests have shown that a small amount of alcohol caused the keys to be released more rapidly than before alcohol was taken, but the person tested released the wrong key much more frequently than before. This effect of alcohol in making the individual more liable to quick and unconsidered judgments is one of the chief causes of the decrease in efficiency.

Alcohol lowers moral standards. Human society through countless generations has built up standards of conduct and ideals of right and wrong. The individual has also developed will power and the ability of self-restraint. This ability is under the control of the highest center of the nervous system, the brain. One of the first effects of alcohol is to dull or paralyze this nerve-center, and the individual loses the qualities which distinguish him from the savage. A person under the influence of alcohol will do and say things which he will not do or say when he is in full possession of his senses. In the occasional drinker, this dulling of the sense of right and wrong is only temporary, but there is always the grave danger that its use will become habitual. The result of such long-continued habit is a complete breaking down of the refinements which modern civilization has made, and moral degeneracy results.

Tobacco is especially harmful to growing boys and girls. The effect of tobacco upon the human system has also been a subject of investigation by scientists. Their findings have shown that it is especially harmful to young people. Most of the states have recognized this by passing laws which prohibit the sale of tobacco to minors. Not only is the use of tobacco an offensive habit, but experiments have demonstrated that the average scholarship of tobacco-users in schools and colleges is lower than that of students who do not use tobacco. Colleges and high schools which are leaders in athletics have also found that the use of tobacco interferes with the efficiency of their athletes, and have prohibited the use of tobacco by the members of their athletic teams. In general, experiments

have shown that tobacco has at least three bad effects on the human body: (1) it interferes with the growth of the heart and produces a weakened condition known as "tobacco heart"; (2) it interferes with the respiratory system by irritating the delicate membranes of the throat and lungs; and (3) it interferes with the action of the digestive juices. These findings indicate that the tobacco habit is decidedly injurious.

PROBLEM 6: HOW CAN YOU TAKE CARE OF YOUR EYES?

Our eyes contribute more to our happiness and our success in life than any of the other sense organs. If they are not properly cared for, such neglect may not only result in defective sight but may also affect the nervous system, causing headaches and a general decline in health. A knowledge of how to take care of the eyes is dependent upon an understanding of how they work.

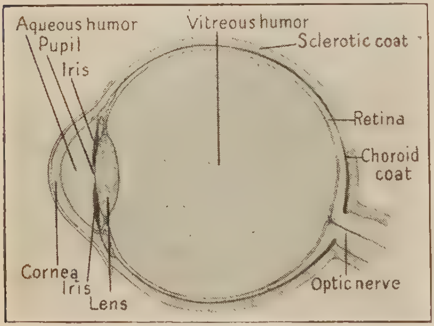


Fig. 148. The Eye

This is what the eye would look like if cut in halves from front to back.

How our eyes are constructed. If you could see a section of your eye, it would appear as shown in Figure 148. This "ball of your eye" is really ball-shaped. It is set in a bony socket and further protected by the eyelids and eye-lashes. Muscles are attached to the eyeball so that it can be turned easily and quickly in different directions.

A study of the structure of the eye will help you to understand how it works. Starting on the outside you find a tough outside coat around the entire eyeball, except where the *optic nerve* leaves at the back. This coat, called the *sclerotic coat*, is white in color, except in the central part of the front of the eye, where it is transparent. This transparent part is

called the *cornea*. It is the window through which light can enter the eye. The white part around the cornea is often called the "white of the eye."

Inside the sclerotic coat is a second covering called the *choroid coat*. This has a circular opening in front, directly back of the cornea. The part of the choroid coat around this opening looks much like a circular curtain, and is called the *iris*. The color of this curtain varies, giving different colors to different eyes. The iris is controlled by small muscles so that the opening can be made smaller or larger. The opening is called the *pupil*. Its size governs the amount of light which can enter the eye.

The inside coat of the eye is called the *retina*. This is the sensitive part. It receives the light which enters the eye and produces the picture. It acts much like the film or plate of a camera. Many small branches of the optic nerve end in the retina. These nerve endings are affected by the light, and send their sensations to the brain, making a mind-picture of the objects and colors seen.

Directly back of the iris is a transparent *lens*, shaped something like a burning-glass or the lens in a camera (Figure 148). Since it bulges out on both sides, it is called a *double convex lens*. It is made of soft material, and its shape is readily changed by means of muscles attached to it. The muscles can make it thinner or flatter and thicker or rounder, as necessary. The space behind the lens is filled with a transparent jelly-like substance called *vitreous humor*. This keeps the eyeball round. Between the cornea and the lens is a clear liquid called the *aqueous humor*.

How we see. When we see an object, it is because that object is sending light to our eyes. The light from the sun, an electric light, or some other light-giving body may come directly to the eye or be reflected from some object. When the rays of light from the object enter the eve, they pass through the lens, which bends them, changing their direction before they strike the retina.

Experiment 35: How is the direction of light changed by a double convex lens?

(*a*) Obtain a burning glass or a reading glass which is a double convex lens. Darken the room and light a candle. Hold the

Fig. 149. How a Double Convex Lens Acts

Note that the rays of light which pass through the lens are bent, and are thus brought to a focus.

lens a foot or two in front of the candle (Figure 149), and then hold a piece of paper back of the lens so that a distinct *image* of the candle will fall on the paper. The candle is then said to be in *focus*. Note how far back the paper is from the lens.

(*b*) Repeat (*a*), holding the lens more than a foot or two in front of the candle. How far back of the lens must the paper be held to get a distinct image?

From this experiment you see that objects close to a lens come to a focus farther back than objects far away from a lens. Since the retina upon which the image comes to a focus in the eye is always the same distance back of the lens, the eye must have some method of bringing the rays of light from distant and near objects to a focus. This is accomplished by changing the shape of the lens.

Experiment 36: How does the shape of the lens change the focus of the rays?

(*a*) Obtain two double convex lenses, one more convex than the other.

(*b*) Place a candle two feet in front of the flatter lens and bring the candle to a focus on a piece of paper held behind the lens.

(*c*) Repeat (*b*) with the second lens, keeping the candle the same distance in front of the lens. How do the distances between the lens and the paper differ for the two lenses?

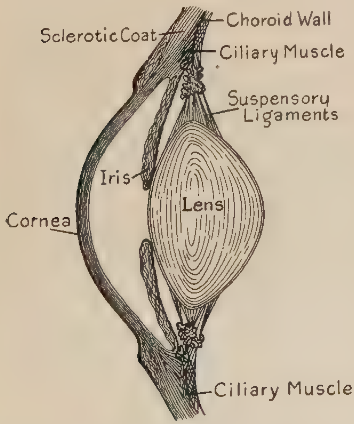


Fig. 150. Attachment of the Lens to the Choroid Coat

The muscles are between the choroid and sclerotic coats. Shortening of the muscles pulls down the choroid coat.

From the experiment you see that the more convex the lens, the closer the focus will be.

The muscles which hold the lens of the eye are attached to the choroid coat (Figure 150). When these muscles contract, the pull on the lens is lessened, and the lens becomes thicker or more convex. When the muscles relax, the choroid coat goes back into place and pulls on the lens, making it flatter. You can now understand how the eye can bring far and near objects into focus. When an object is close to the eye, the image would tend to fall back of the retina. In order to prevent this, the muscles contract and make the lens more convex so that the image will come to a focus on the retina. By changing the pull on the lens, the muscles are therefore able to change the convexity of the lens so that the image will always fall upon the retina (Figure 151).

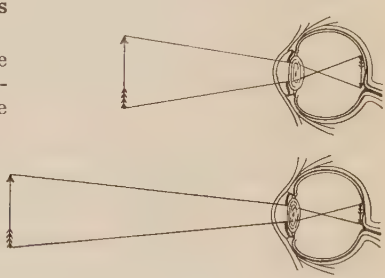


Fig. 151. How the Eye Focuses for Near and Far Objects

In the upper drawing, the object is near the eye and the lens is convex. In the lower drawing the object is farther away from the eye and the lens is less convex.

How to avoid eye strain. If you study or read for too long a time, you are conscious of a sense of eye strain. This is due to the fact that the muscles holding the lens must be kept contracted so that the page will stay in focus. This *fatigues*, or tires, the muscles, causing a strain. Usually this can be avoided by looking up occasionally and focusing the eye on some distant object so that the muscles will relax. Too bright a light or too dim a light also causes eye strain. When possible, the light should come from the left side so that the shadows cast by the right hand will not fall on the work.

Some eyes are defective. Often the eyes themselves are so defective that they will not focus properly for far and near objects. Defects of this kind can only be remedied by the use of glasses. If you are unable to see both far and near objects distinctly or if sometimes objects appear blurred, you should go to a good oculist and have your eyes examined.

Exercise 10. Far- and near-sightedness are sometimes caused by the size of the eyeball, which may be too long or too short. Is the eyeball too long or too short in near-sightedness? In far-sightedness? Prove your answer by making a drawing something like Figure 151.

Exercise 11. Glasses are worn to correct the defects of near-sightedness and far-sightedness. Convex glasses bring the focus closer to the lens; concave glasses throw the focus back farther from the lens. Which type of glasses would correct near-sightedness? Far-sightedness?

Exercise 12. Write a paragraph entitled "How I can take care of my eyes."

PROBLEM 7: WHAT CAN YOU DO IN CASE OF ACCIDENT?

Very few people pass through life without coming into contact with a situation in which they need a knowledge of first aid to the injured or sick. Of course, a doctor is necessary in a great many cases, but doctors are not always on the spot, and in most instances a great deal can be done before the doctor arrives.

Cuts and scratches should be treated. Perhaps the simplest case of first aid is presented by injuries due to cuts or scratches. These are not often dangerous, but sometimes the smallest cut or scratch may cause death. For this reason they should be treated. The first thing to do is to make them bleed so as to wash out any germs which might *infect* them. This is done by squeezing them well at the sides. If the wound is then painted with iodine and covered with a piece of *antiseptic* gauze, no danger of infection will follow. In case the wound is serious, the clothing should be removed from around it, and the wound exposed to the air. If the wound is bleeding freely, it should be bandaged tightly with antiseptic gauze, and a doctor should be called at once.

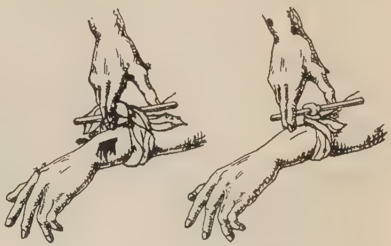


Fig. 152. Stopping a Bleeding Artery

In case of a cut artery bleeding must be stopped. In some cases the blood may come in jets or spurts. This shows that an artery has been cut, and it is necessary to check the blood flow immediately. Pressure therefore should be applied to the artery between the wound and the heart. In case the injury is in an arm or leg, this can be done most effectively by tying a knot in a handkerchief and laying this over the artery (Figure 152). Insert a stick through the bandage and twist it so that the knot will apply pressure to the artery, and thus stop the bleeding. Loosen the bandage occasionally to see if the bleeding has stopped, because if it is kept tightened too long it will cause trouble. In cases of this kind a doctor should be summoned as quickly as possible.

Bruises and sprains should be treated with cold applications. Bruises and sprains may also be treated by first aid. Bruises should be treated by placing something cold on them. A cloth which has been wrung out in cold water is usually

sufficient. In cases of sprain, cold applications are also desirable. Severe sprains should be treated by a physician.

Drowning and suffocation demand artificial respiration. The body must always be able to take in good air and get rid of bad air. Inability to do this causes *suffocation.* When a person has been under water for some time or in a room

Courtesy U. S. Bureau of Standards

Fig. 153. Artificial Respiration

This method of artificial respiration may be used not only in drowning and suffocation, but also in cases of severe electric shock where unconsciousness has resulted.

containing poisonous gases, breathing stops. These persons frequently can be brought back to consciousness by helping them to breathe. The American Red Cross textbook on *First Aid and Relief Columns* gives the following directions:

The patient is laid on the ground, face down. The arm may be stretched out at full length over his head, or one arm may be bent so the forehead rests upon it. In either case the face must be placed slightly to one side so that the ground will not block off the air from nose and mouth. As soon as the patient is in proper position, the operator kneels at one side, or astride the body, but without resting his weight upon it (Figure 153). The palms of his hands are placed on the short ribs across the small of the back, with the thumbs nearly together. The operator, by let-

ting his weight fall on his wrists and by bending his body forward, decreases the size of the chest and the air is expelled from the lungs. The pressure is then released by the operator swinging backward; the elastic chest springs out to its original size, and the air is drawn into the lungs. The movement is at the rate of twelve to fourteen a minute. Better time with a watch.......... Whatever the method of artificial respiration used, it should be kept up for at least an hour and a half.

Injuries due to heat and cold need special treatment. Another class of injuries which need special attention are those due to heat and cold, such as burns and scalds, sunstroke and frost-bite. Burns and scalds should be treated by excluding the air. Vaseline, olive oil, cream, or a thin paste made of baking soda can be used. The burn should then be lightly bandaged. Except in cases of severe burns, a doctor is not necessary. In cases of sunstroke a doctor should be sent for at once, and in the meantime the patient should be treated by rubbing cold water or ice over the face, chest, neck, and arm-pits. The object of such treatment is to reduce the body temperature. In cases of frost bite the frozen part should be brought back to normal temperature slowly. This may be done by rubbing the affected part with snow or cold water, and then gradually use warm and warmer water.

Foreign bodies in the eye must be removed. Sand, cinders, or particles of dust in the eye cause a great deal of pain. In removing them, the first thing to remember is not to rub the eye, because such rubbing may injure some of the delicate parts. If the eye is closed and the tears allowed to accumulate, the object will frequently be washed out. Or the upper lid may be pulled down over the lower several times. Sometimes if the nostril on the opposite side is closed and the patient blows his nose very hard, the desired result will be secured. If this does not remove the object, have the patient look up, press the lower lid down, and examine the lower surface. If the object is seen, wipe it off with the corner of a clean handker-

chief or with a piece of cotton. To remove objects under the upper lid, have the patient lean back in a chair, place a pencil across the upper lid, and turn the lid back over the pencil. The patient should look downward.

Exercise 13. Write a paragraph on first aid to the injured for each of the injuries mentioned in this problem.

Review Exercise on Unit V. Turn to the Table of Contents of Unit V and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT V

1. Place a piece of cracker in your mouth and chew it for several minutes. Why does the cracker become sweet?

2. Make a list of as many chemical changes as you can.

3. Make a drawing of your mouth, showing the number of teeth you have.

4. Examine the different figures of this unit and list the organs of the body that are shown. Describe after each organ its location in the body.

5. It is not a good plan to exercise vigorously immediately after eating. Why?

6. Examine a camera; state in what respects it is like the eye.

7. Why are lenses used in cameras and motion-picture machines?

8. Make a set of health rules which you will try to follow. Consider all points you have learned in this unit.

9. Make a drawing of your sleeping room, showing the position of the bed, windows, and doors. Explain how you ventilate your room at night.

10. Determine your rate of breathing per minute: (*a*) while standing, (*b*) while lying down, (*c*) after strenuous exercise. How do you account for any differences in the rates?

UNIT VI

SELECTING AND CARING FOR OUR CLOTHING

Preliminary Exercises

1. Why do you wear heavy clothes in winter and light clothes in summer?

2. Of what materials are your clothes made?

3. What difference is there in the fur of animals living in cold regions and those living in hot regions? Think of specific animals.

4. How and where is cotton grown?

5. How is cotton made into cloth?

6. How is wool obtained?

7. How is the fiber from flax made into cloth?

8. How are spots on clothing commonly removed?

9. How are clothes laundered?

10. Make a list of as many kinds of cloth as you can.

Underwood and Underwood

Fig. 154. African Drum-Beaters

THE STORY OF UNIT VI

The kind of clothing which people wear depends to a great extent upon the climate. Of course, there are great differences in the cut and style of clothes, which have no relation to climate, but even the prevailing fashions follow the dictates of Mother Nature. In regions where it is hot the year round, as in parts of Africa, the chief characteristic of clothing is its scantiness (Figure 154). In the land of the Eskimo heavy

furs and hides are the prevailing mode (Figure 155). In our own country, where the climate changes from season to season, a great variety of clothing is worn.

Clothes are necessary to protect our bodies from the heat and cold. You all know that the temperature of the healthy human body is always the same. It varies somewhat in different persons, but it is approximately 98.6°F. At this temperature our bodies feel most comfortable and can work most efficiently. The body is like a gasoline engine: it will not deliver its full power when it is too hot or too cold. When you go out on cold days, the body must be sufficiently covered so that the heat produced inside you cannot escape. Otherwise the body may get chilled. On hot days the problem is to wear clothing which allows the body heat to escape and which will not absorb too much heat from the outside air. Selecting the proper kind of clothing and clothing materials to adapt oneself to changes in climate depends on one's knowledge of the different materials and on common sense.

Courtesy Pathé Films

Fig. 155. An Eskimo Hunter

Compare his clothing with that of the African drum-beaters in Figure 154.

If you go into a dry-goods store or look in the windows of a big department store, you see all kinds and colors of materials from which clothing is made. If you ask the names of the different kinds of goods, you will hear such words as dimity, organdy, mohair, crêpe de Chine, swiss, lawn, crash, serge, worsted, linen, velvet, velour, satin, cashmere, tweed, voile, calico, and many others. All of these different kinds of cloth,

or *fabrics*, are made from four kinds of raw materials, or *fibers:* wool, silk, cotton, and flax. We can go still further and classify the fibers as either animal or vegetable fibers. Wool comes from sheep, silk is spun by the silkworm (Figure 156), cotton grows on the cotton plant (Figures 157 and 158), and linen is made from the fibers of the flax plant. Fabrics may be woven from a single raw material, or they may be a mixture of different materials. The different kinds of cloth are due to differences in weave and to the kinds of fiber they contain, but each may be classified as wool, silk, cotton, linen, or mixed goods.

Courtesy Corticelli Silk Co.

Fig. 156. Cocoon of the Silkworm

The worm spins around its body this cocoon made of fine silk fibers.

Each kind of material has certain properties which make it valuable for use as clothing. For our summer clothes we use one kind of material; for our winter clothes we use another. Clothing worn next to the skin must also have different properties from clothing worn as outer garments. In addition to the fibers which are used to make clothing, two other materials are in general use, rubber and leather. By the use of these materials we secure added warmth and protection for our clothing and bodies on rainy days. Thus by varying the kind of clothing worn, we can successfully adapt ourselves to hot and cold as well as to wet and dry weather.

Fibers may be distinguished from each other, because each has certain physical and chemical properties. Each kind of fiber possesses certain characteristics which identify it if it is examined under a high-power microscope. This is probably the surest test, although there are others that may be used.

Some fibers absorb water or oil more rapidly than others; this test may be used to distinguish them. Experts can generally tell the kind of fiber by the feel of the cloth. Tests like those described above are called *physical tests.* Vegetable fibers can be distinguished very easily by burning them or by treating them with certain chemicals, as you will find in a later

Courtesy International Harvester Co.

Fig. 157. Harvesting the Cotton Crop

Cotton ripens slowly and not all at once; so the fields have to be gone over several times during a period of two or three months.

experiment. Cotton cannot be distinguished from linen by a chemical test because they are both composed of the same elements: carbon, hydrogen, and oxygen. Silk is composed of carbon, hydrogen, oxygen, and nitrogen; and wool contains the same elements as silk, with the addition of sulphur. Because of their different composition, these fibers can be distinguished by *chemical tests,* that is, by seeing how different chemicals act upon them.

Economy, sanitation, and our own pride demand that we keep our clothes clean and in good condition. You probably

have never thought that there is science in "washing clothes," but if you watch some one "do a washing" you will see many things which will puzzle you. You know that different chemicals, such as washing soda and borax, are used, but do you know why? Some clothes are washed in very hot water and may be rinsed in cold water, but others must be washed in warm water and rinsed in water of the same temperature. Some clothes may be rubbed vigorously on a washboard, while others should not be. By making good soapsuds the labor required to get the clothes clean is greatly reduced, but different kinds of soap must be used for different fabrics. The method of washing clothes depends upon the chemical nature and the kinds of fibers which make up the cloth.

Courtesy International Harvester

Fig. 158. A Cotton Boll

At the right of the boll is shown a pod about ready to burst.

Spots and stains usually cannot be removed by the ordinary laundering process. In cleaning of this kind it is first necessary to determine the kind of stain. One must know whether it is grease, ink, paint, mildew, blood, grass, or rust, and each kind of stain must be removed by a different method, depending upon the chemical nature of the stain and of the fiber.

PROBLEM 1: HOW DOES CLOTHING KEEP US WARM OR COOL?

The body must regulate its temperature. During the summer time when it is very warm, the clothing must help the body get rid of heat and also keep the heat of the air from warming the body. During the winter it must prevent the loss of heat. The body itself has several methods of keeping its temperature constant, but sometimes the heat-regulating mechanism of the body is interfered with by the clothes we

wear. We must, therefore, first understand how the body regulates its temperature.

Heat and energy are produced in the body by the combination of oxygen with the food which one eats. (See page 85.) The amount of heat produced depends upon the quantity of heat-producing foods which are eaten and upon the amount of oxidation which takes place within the body. On very hot days when one exercises vigorously more heat may be produced than is necessary to keep the body at the correct temperature (98.6°F.); consequently, the body must get rid of some of its heat. You have already seen that under such circumstances the blood vessels in the skin get larger, and greater amounts of blood flow through it. (See page 158.) If the body is warmer than the surrounding air or clothing, some of its heat changes to radiant energy (see page 40), and the body thus loses heat. We say that the body loses heat by *radiation*. The amount of heat changed to radiant energy depends upon the difference between the temperature of the body and that of its surroundings. When the blood vessels in the skin are *dilated*, that is, when the muscles are relaxed, more blood flows through the skin, and more heat is changed to radiant energy.

The body is also cooled by passing on some of its heat to the clothing and air.

Experiment 37: How does the body give up heat?

(*a*) Obtain a piece of metal. Allow it to remain in the room long enough to have the same temperature as the air in the room.

(*b*) Touch the piece of metal with your finger. Does it feel cold or warm?

The metal is at a lower temperature than the body. Heat therefore passes from the body to the metal. The particles of which the metal is composed are able to pass this heat along to the other particles, that is, to *conduct* the heat. The metal feels colder than other objects in the room, such as the table, because the metal conducts heat away from the body.

Likewise, air and clothing in contact with the body conduct heat away from the body if they are at a lower temperature.

A third way in which the body loses heat is by pouring perspiration on the skin. (See Figure 146, page 157.) Part of this perspiration evaporates directly from the skin, and part is absorbed by the clothing and then evaporated.

Experiment 38: What effect does evaporation of a liquid have upon the temperature of the body from which it evaporates?

Take the temperature of the room. Tie a small piece of cotton around the bulb of the thermometer. Dip the bulb of the thermometer in some water which is at room temperature. Remove the thermometer from the water and allow it to stand for one minute. Note the temperature. Read the next paragraph and explain it on the basis of this experiment.

It requires heat to change water or any liquid to a gas. The perspiration which is given off through the skin changes to water vapor, and the heat necessary to make it do this is taken from the body, which is thereby cooled.

Under certain conditions water evaporates quickly, and under other conditions it evaporates slowly. The rate at which it evaporates can be measured by the cooling effect. The following experiment shows the effect of air currents and the amount of water in the air upon the rate of evaporation.

Experiment 39: Upon what does the rate of evaporation depend?

(*a*) Repeat Experiment 38 and note the number of degrees change in temperature.

(*b*) Fan the thermometer which has the wet cotton on the bulb. Note the temperature and compare with the results obtained in (*a*). What effect does the movement of the air have upon the rate of evaporation? Remember that the greater the evaporation, the greater will be the cooling effect.

(*c*) Pour water into a test tube to a depth of one-half inch. Cork the test tube tightly and allow it to stand until the next day. The air in the test tube will be saturated with water vapor. On the next day insert a thermometer in a one-holed cork which will

fit the test tube. Tie a small piece of cotton around the bulb and moisten it. Then quickly remove the cork from the test tube and insert the cork containing the thermometer. Push the bulb of the thermometer down into the water and record the temperature. Then raise the thermometer until the bulb is in the saturated air. Allow the thermometer to stay in this position for one minute and then read the temperature. Compare the temperature change with the results obtained in (*a*). What effect does the presence of a large quantity of water vapor in the air have upon the rate of evaporation?

The rate of evaporation from the body is increased by contact of the body with a current of air; it therefore loses heat much faster than when it is surrounded by still air. This explains why you become chilled when sitting in a draft or wind after exercising. When the air is very humid or full of water vapor, evaporation takes place very slowly. Under such conditions the body cannot lose much heat by evaporation.

Exercise 1. Explain how the body automatically keeps its temperature at about 98.6°F.

Clothing assists the body in maintaining an even temperature. The rate at which the body loses heat by conduction and radiation and by the evaporation of perspiration can be largely controlled by the selection of the proper kind of underwear and outer clothing. In the summer time underwear must be made of materials which will absorb the perspiration quickly and which will lose it rapidly. Cotton and linen possess these characteristics and therefore make satisfactory summer underwear. Silk also absorbs water quickly and loses it rapidly, but its high cost prevents general wear. The outer clothing in the summer must also lose its moisture quickly, because if it does not, the layer of air between the inner and outer clothing will become saturated with water and prevent evaporation from the skin. Outer clothing for summer wear is largely cotton, linen, silk, or a mixture of wool with cotton and silk.

The most noticeable difference in summer and winter clothing is the difference in color. Dark-colored clothes are worn in the winter and light-colored clothes in the summer. In the summer time we receive much radiant energy from the sun. This energy is absorbed by our clothing, and the heat is conducted to the body. The amount of energy absorbed depends somewhat on the color of the material, as shown by the following experiment.

Experiment 40: Which absorbs more radiant energy, light- or dark-colored cloth?

Obtain two test tubes of the same size. Wrap a piece of white cotton cloth around one test tube and a piece of dark cloth around the other. Arrange them as shown in Figure 31, page 40. Now place the apparatus in bright sunlight, and after several minutes read the temperature in each tube. Which of the two pieces of cloth absorbs the more heat? Explain how the experiment shows this.

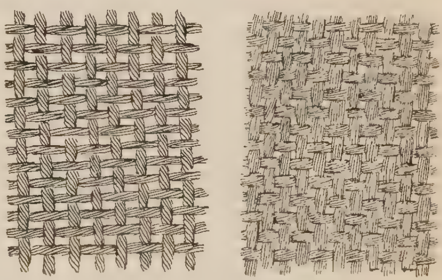


Fig. 159. Loosely Woven and Tightly Woven Fabrics

In winter the greater amount of heat is lost from the body by conduction and radiation, because the amount of perspiration which evaporates from the body is small. The problem of selecting clothing in winter is that of securing materials which will not readily conduct heat. Wool is the poorest conductor of heat and can be woven very loosely. When woven loosely, it contains large air spaces between the meshes (Figure 159). Air is a very poor conductor of heat and thus aids the wool in preventing loss of heat by conduction. For undergarments a mixture of cotton and wool is superior to all-wool, because the cotton prevents the closing of the mesh when the wool is washed. For outside

wear in the winter, wool is the most satisfactory material because of its weight, its looseness of weave, and its non-conductivity of heat.

Rubber and leather do not absorb water readily. Water cannot pass through rubber, which is, therefore, used for raincoats and for overshoes. Leather does not absorb water readily, and can be made waterproof by certain waterproof dressings which fill up the pores. Damp clothing of any kind is very dangerous to the wearer, especially in the winter when he may be exposed to drafts. The evaporation of the moisture rapidly lowers the body temperature and makes it easy to "catch cold." A good raincoat and a pair of rubbers are necessities for everyone, and will more than pay for themselves by keeping one's clothes and shoes in good condition and by preventing sickness.

Exercise 2. State the advantages and disadvantages of each kind of fabric when worn as outer garments in the summer. In the winter.

Exercise 3. State the advantages and disadvantages of each kind of fabric when worn as undergarments in the summer. In the winter.

PROBLEM 2: HOW CAN YOU KNOW THE KINDS OF FIBERS IN YOUR CLOTHES?

Some time in the future a law will probably be passed requiring cloth manufacturers to label their goods with such marks as "all linen," "half cotton," "wool," or "wool and cotton." Until that time comes the purchaser must have some way of telling whether a material is what it is said to be. There are many ways of *adulterating* fabrics, that is, adding foreign materials to them. One is to weight the cloth by filling the open mesh with gums, clays, starches, or other materials. After the cloth is washed, these materials fall out and leave a much more open mesh or weave. Silk is very commonly adulterated in this fashion to increase its weight. A common practice is to combine cotton and wool, or cotton and linen, and then

sell the product as fine wool or pure linen. Cotton is sometimes treated with chemicals so that it resembles silk or linen. Rubbing the cloth between the fingers or examining the threads which make up the *warp* and *woof* (lengthwise and crosswise threads) (Figure 160) will give experienced buyers an indication of what the cloth contains, but inexperienced purchasers must rely on other tests.

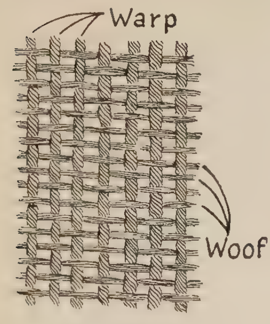


Fig. 160. Lengthwise and Crosswise Fibers

The lengthwise fibers are usually heavier than the crosswise fibers and are twisted to give strength.

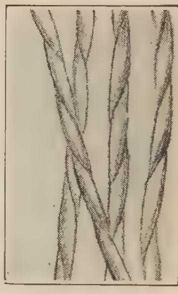


Fig. 161. Cotton Fibers

These fibers are magnified about 180 times.

Microscopes are used to test fibers. Each kind of fiber has a certain characteristic appearance when examined under a microscope. The cotton fiber has a natural twist, and under the microscope it appears as a twisted, smooth, flat band (Figure 161). The fibers are from one to two inches long and have a diameter of about .0007 inch. A small thread is composed of thousands of these tiny fibers so interwoven that it is difficult to distinguish them. The wool fiber under the microscope appears kinky and has an outer covering like the scales of a fish, each scale overlapped by the one above (Figure 162). These scales are really tiny cells which make up the outer covering of the wool. The fibers of flax, which are used to make linen, appear rod-like under the microscope, with occasional markings which do not

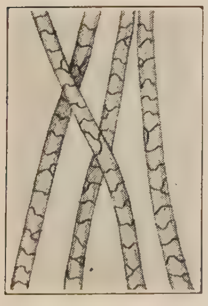


Fig. 162. Wool Fibers

Wool fibers are obtained from different animals and vary somewhat in appearance.

overlap (Figure 163). Silk fibers have no characteristic markings (Figure 164). If you have a compound microscope, examine different fabrics and identify the fibers. The microscope test is the one commonly used by large stores, and by its use adulterated materials and mixed goods are quickly detected.

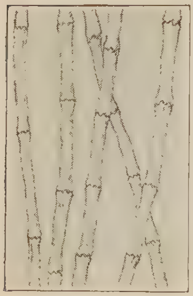


Fig. 163. Flax Fibers

These fibers are obtained from the stem of the flax plant.

Fibers may be tested at home. To determine the kind of fibers in a fabric when a microscope is not available, it is necessary to use certain chemical or physical tests, such as those given in the following experiment.

Experiment 41: How can fibers be identified?

1. *Burning test*

(*a*) Obtain a piece of cotton cloth. Light a small piece with a match. Observe the odor, the color of the flame, and the rapidity of burning.

(*b*) Repeat (*a*), using linen.
(*c*) Repeat (*a*), using wool.
(*d*) Repeat (*a*), using silk.

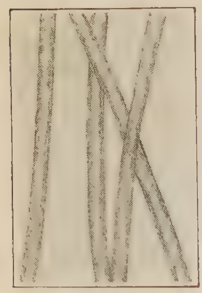


Fig. 164. Silk Fibers

Silkworms force from their bodies a colorless liquid which hardens in the air, forming smooth tubes of silk fiber.

2. *Litmus test*

(*a*) Moisten a strip of blue litmus paper. Heat a piece of cotton in a dry test tube and hold the litmus paper in the smoke which comes from the tube. Note the color change. Repeat, using a strip of red litmus paper, and note any color change.

(*b*) Repeat (*a*), using linen.
(*c*) Repeat (*a*), using wool.
(*d*) Repeat (*a*), using silk.

3. *Lye test*

(*a*) Make a solution of two teaspoonfuls of lye to a cup of water or use a five per cent solution of sodium hydroxide. Place a piece of cotton in a test tube. Add about a half-inch of the solution and boil for about

five minutes. Pour the solution and cotton out into a small dish. Remove the cotton from the lye with a pair of forceps, and rinse it in water. Test the strength of the cloth.

(*b*) Repeat (*a*), using linen.
(*c*) Repeat (*a*), using wool.
(*d*) Repeat (*a*), using silk.

4. *To distinguish cotton from linen*

(*a*) Obtain a piece of mixed cotton and linen fabric. Place it in a beaker of water to which have been added two or three drops of hydrochloric acid, and heat. This will remove the starch and other materials which have been added to the cloth to make it stiffer.

(*b*) Allow the fabric to dry and then place a drop of olive oil on it. Note that the linen threads absorb the oil more rapidly than the cotton threads.

5. *To distinguish wool from silk*

(*a*) Heat a piece of wool in a test tube. Hold a strip of filter paper moistened with lead acetate at the mouth of the tube. Result?

(*b*) Repeat (*a*), using a clean test tube, with silk. Does the paper change color?

Exercise 4. Make a table in the form shown below, but much larger so that you can write in the results of the tests which you made.

	Burning Test	Litmus Test	Lye Test	Olive Oil	Lead Acetate
Cotton......					
Linen.......					
Wool.......					
Silk........					

What tests would you make in determining the kind of fibers in a piece of cloth? Name the tests in order, and tell why you would use these tests. If time permits, try your plan; test many kinds of cloth.

PROBLEM 3: HOW ARE CLOTHES LAUNDERED?

There are two principal classes of substances which must be removed by washing: (1) body perspiration which contains oily materials, and (2) particles of dirt or grease caught in the meshes of the fabric. These are usually removed by the use of soap or other chemicals.

Soap is the most common substance used for washing clothes. Did you ever try to wash grease from your hands with plain water? A sticky, greasy mass is the only result; the water will not remove the grease. But the addition of soap, followed by rubbing, will remove it. How does the soap work?

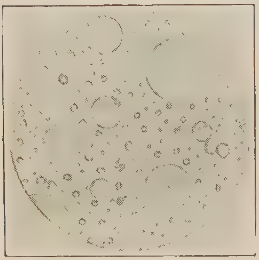


Fig. 165. An Emulsion of Oil

One drop of oil was emulsified to form these droplets.

Experiment 42: Why does the addition of soap to water help remove grease?

(*a*) Put 100 c. c. of water in a flask or bottle. Add ten to twelve drops of olive oil. Shake the flask vigorously. Does the oil mix with the water? Allow the flask to stand until the next day. Are the oil and water mixed?

(*b*) Rub some soap in 100 c. c. of water until good suds or lather is formed. Pour this into a bottle, add ten to twelve drops of olive oil, and shake vigorously. Do the oil and the soap solution mix? Let the mixture stand until the next day. Compare results with those of part (*a*) of the experiment.

When a greasy fabric is rubbed with soapy water, the particles of grease are broken up into finer particles. Each of the finer particles is surrounded by a film of soapy water and is *suspended*, or floats, in the soapy water in the form of a tiny drop. This is called an *emulsion* (Figure 165). The soap is said to *emulsify* the oil or grease. These small emulsified particles of oil or grease may then be carried away by rinsing the fabric.

Soft water is better than hard water for the laundry. Practically all natural water, with the exception of rain water, contains minerals which have been dissolved out of the rocks and soil. Water which contains but few minerals is said to be "soft," while water which contains large quantities of certain minerals is called "hard water." For laundry purposes the soft water is more satisfactory than hard water.

Experiment 43: Why is soft water more desirable than hard water for laundry purposes?

(*a*) Make a soap solution by placing Ivory or castile shavings in a bottle of rain water or distilled water. Add shavings until no more soap will dissolve after the bottle is well shaken.

(*b*) To a test tube half full of distilled water or rain water, add the soapy water made in (*a*) drop by drop (use a medicine dropper), shaking after each drop. (The test tube should be stoppered, or covered securely with the thumb, while shaking.) When a layer of lather about one-half inch deep remains on top of the water for a minute, the test is complete. How many drops are necessary to make this lather?

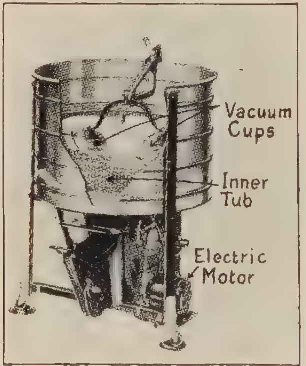
(*c*) Repeat (*b*), using, instead of distilled water, water from a well or from the city supply. Compare the amount of soap required to make a lather with the amount required for the same volume of distilled water.

(*d*) Make up some very hard water by dissolving some calcium sulphate or magnesium sulphate in distilled water. Repeat (*b*). Hold the test tube up to the light and note the tiny flakes in the water. Compare the amounts required in (*a*), (*b*), and (*c*). What is your conclusion?

The next question which we must answer is, "Why does it take more soap to make suds with hard water than it does with soft water?" When soap was added to the hard water in part (*d*) of the preceding experiment, your attention was called to the white flakes which were formed. These flakes were formed by the combination of the soap with the minerals in the water. The new materials which were formed were not soluble in water; so they separated out as solids. Chemists

say that such insoluble materials are *precipitated*, because they settle to the bottom. Before the soap would form suds, it was necessary to remove all of the minerals which caused the soap to precipitate. After this was done, the soap could form suds and remove the dirt.

Many substances may be used to soften water. When soft water is not available for washing purposes, it is customary to add certain materials, such as borax, washing soda, or ammonia, to the hard water.



Courtesy Laundryette Co.

Fig. 166. An Electric Washing-Machine

The vacuum cups move up and down, and the soapy water is forced through the clothing. There are a number of other types of washers manufactured. What kind do you have at home?

Experiment 44: What effect do borax, washing soda, and ammonia have upon hard water?

(*a*) For use in this experiment make some hard water as in part (*d*) of Experiment 43. Take one-half test tube of this water and determine the number of drops of soap necessary to make a lather.

(*b*) Add a pinch of borax to the same volume of water. What is formed? Determine the number of drops of soap necessary to make a lather after the borax is added.

(*c*) Repeat (*b*), using a pinch of washing soda. Compare the results with (*b*).

(*d*) Repeat (*b*), adding about five drops of strong ammonia water. Compare results with (*b*).

(*e*) Summarize the results of this experiment.

Exercise 5. Write a paragraph on "The Use of Hard Water for Laundry Purposes," telling why hard water should not be used unless softened, how it can be softened, and why soft water should be used.

There are several steps in the proper washing of clothes. When the clothes are soaked, the dirt is softened by the swelling

of the fibers. Wool and silk should never be soaked for a long time in water with soap which contains free lye, or *alkali*, or in water containing washing soda. In both cases the alkali in the soap and the alkali formed by the washing soda will attack the fiber and weaken it. Wool and silk should never be soaked in hot water and immediately put into cold water. Both the wool fiber and the silk fiber, being composed of animal material, are very sensitive to heat and cold. In wool, you remember, the outer covering consists of scale-like cells which overlap. In the presence of alkalies or in changing from hot to cold water, the scales interlock and the fibers shrink to a felt-like mass. This is called *felting* (Figure 167). Cotton and linen and all vegetable fibers are little changed by the action of alkalies or by hot and cold water.

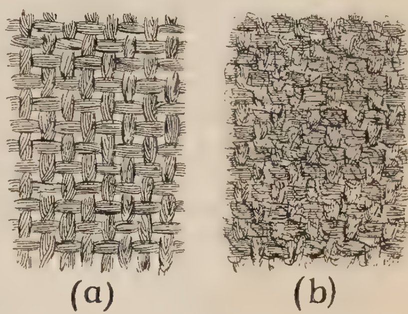


Fig. 167. Wool Fabrics Before and After Felting

(*a*) Fabrics before felting; (*b*) fabrics after felting.

Exercise 6. Why do woolen sweaters sometimes shrink and lose their soft feel when washed?

After clothes are soaked for an hour or two, it is the custom to rub them on a washboard or to place them in a washing-machine (Figure 166). This assists the action of the soap by bringing it into closer contact with the particles of dust and grease, and thus helps remove them from the clothes. Too much rubbing will cause wool to felt and lose its softness and elasticity. Hard rubbing also breaks the fibers of silk, weakens them, and takes away the luster. Cotton and linen materials may be rubbed without injury, but in the case of colored materials, more soaking and less rubbing are desirable.

All soap, dirt, and materials released by the action of water-softeners must be removed by *rinsing* in water. It is much better to rinse in warm water, because the soap will dissolve better in warm water than in cold. In rinsing wool or silk the temperature of the rinsing water should be as near that of the washing water as possible. Cotton and linen may be rinsed in either cold or hot water, because heat has very little effect upon vegetable fibers.

Generally the clothes are whitened by means of *blueing*. Did you ever notice what appeared to be rust stains on clothing? One kind of blueing contains iron. Alkalies, such as are found in some soaps and washing soda, act chemically upon this blueing, forming iron rust, thus leaving a stain on the fabric. To prevent rust from forming, it is only necessary to rinse the clothes carefully in order to make sure that all of the alkalies are removed. After blueing, the clothes are wrung out and hung up to dry.

Exercise 7. State the steps in washing clothes, and explain the importance of each step.

Exercise 8. In what ways should the washing of animal and vegetable fibers differ?

PROBLEM 4: HOW ARE SPOTS AND STAINS REMOVED FROM CLOTHING?

In removing spots and stains from clothing two things must be kept in mind: (1) the nature of the fabric, and (2) the kind of stain. The vegetable fibers which compose cotton and linen are very resistant to the action of chemicals and are not easily injured by rubbing. The animal fibers which compose wool and silk cannot be treated with as strong chemicals or rubbed so vigorously as the vegetable fibers. There are three general methods of removing spots and stains: (1) by dissolving the stain in some material such as water, alcohol, gasoline, benzine, naphtha, chloroform, or carbon tetrachloride; (2) by absorbing the stain with blotting paper, powdered French chalk, or magnesia; and (3) by chemical action.

The first thing to do in removing a stain is to determine the kind of stain. Look over your own clothes and find some spots or stains. What kinds are they? There are many varieties, but we shall study the removal of only the common ones.

Experiment 45: How can grease spots and stains be removed by dissolving the stain or grease?

(*a*) Make a small grease spot on a piece of cloth by placing a drop of oil on it. Moisten a rag with one of the following substances: benzine, gasoline, naphtha, ether, chloroform, alcohol, or carbon tetrachloride. (Caution: All of these liquids, with the exception of carbon tetrachloride, are inflammable. Keep away from a flame.) Always rub from the outside of the spot towards the center. Why? If one of the liquids will not remove the spot, try others until one is found that will.

(*b*) Place a little fruit juice on a piece of white cloth. Pour boiling water through the cloth. Result? Explain.

Experiment 46: How are grease spots and stains removed by absorbing the grease or stain?

(*a*) Place some powdered French chalk or magnesium carbonate over a grease spot on a piece of cloth. Allow it to stand for several hours. Result? How is the grease removed?

(*b*) Place a piece of cloth with a grease spot on it between two blotting papers. Press with a hot iron. Result? What is the purpose of the hot iron? Of the blotting paper?

(*c*) Place a drop of ink on any white fabric. Before the ink dries, place the fabric in a cup of milk and let it stand for several days. Remove the fabric and rinse it in water. Result?

In the two methods of removing grease or stains described in Experiments 45 and 46, it was not necessary to use materials which have a chemical action on the grease or stains. Some stains, however, can be removed only by using materials which will act chemically upon them. If the fabric is white, this can be done without danger to the fabric. If the fabric is colored, the action of the chemical may be such as to cause the color of the fabric to change, and great care must be taken.

Experiment 47: How are spots and stains removed by chemical action?

(*a*) Procure a piece of cloth stained with iron rust. Wet the stain with water, touch it with a drop of hydrochloric acid on the end of a stirring rod (Figure 168), and rinse the fabric in water. The iron rust is changed by the acid into a soluble material which washes away. When rinsed, add a drop of ammonium hydroxide, which will act upon any acid which remains to form a new harmless substance.

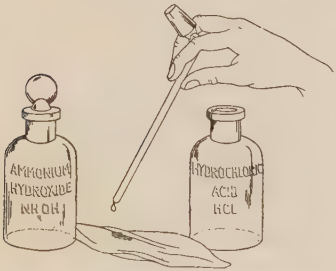


Fig. 168. Apparatus for Experiment 47

(*b*) Obtain a piece of white cotton material and spot it with ink. Make a weak solution of calcium hypochlorite, or, as it is commonly called, bleaching powder. Soak the cotton in the solution and add a few drops of dilute hydrochloric acid. After the spot is *bleached*, rinse thoroughly and dry. The solution of bleaching powder should not be used in bleaching silk or woolen materials because the chlorine attacks the fiber and weakens it.

Exercise 9. Make a list of the kinds of spots or stains which you usually get on your clothes. After each one list the appropriate method of removing it. If you do not know how to remove it, experiment with the methods given until you learn how.

Review Exercise on Unit VI. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit VI and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT VI

1. How does fanning help us get cool? Give two reasons.

2. While swimming, one sometimes feels warmer in the water than on the land, even though the air is much warmer than the water. Explain.

3. Why is a study of clothing included in a science book?

4. How would you determine if a piece of cloth is made of mixed wool and cotton?

5. Why do aviators wear leather-lined coats?

6. Why do some people place newspapers between the mattress and the springs during cold weather?

7. Why do birds "fluff" out their feathers when it is very cold?

8. Why is a wet wool bathing-suit warmer than a wet cotton bathing-suit?

9. Why do we feel more uncomfortable on a hot moist day than on a hot dry day?

10. Why does a rubber raincoat make you feel hot on a summer day?

11. Make a collection of as many kinds of fabric as you can obtain. Mount the samples on cards and label each kind.

UNIT VII

PROTECTING OURSELVES FROM DISEASE

Preliminary Exercises

1. State two health reasons for cooking food.

2. Explain why ventilation is necessary.

3. Summarize your reasons for preserving food.

4. What is the work of your local or state board of health?

5. What can you do in your community to help safeguard the health of your neighbors?

6. Make a list of the diseases you have had, and following each, state, if possible, how you contracted it, how you might have avoided it, and what treatment was necessary to cure it.

7. What is the source of your milk supply? What precautions are taken to insure that it comes to you in a pure condition?

8. What does your city do to prevent danger of disease from polluted water? What does your home do?

9. Why "swat the fly"?

10. Have you ever had any medical treatment to keep you from "catching" a disease like diphtheria or typhoid? How does the treatment serve its purpose?

11. What is a germ, or microbe? Draw a picture of one as you imagine it looks.

12. Why is keeping physically fit the best safeguard against disease?

THE STORY OF UNIT VII

In Unit V you learned the importance of keeping physically fit. You saw that proper care of your body is essential to your efficiency, comfort, and enjoyment in life. In this unit you will learn more about the causes of diseases, and how they are spread. With such knowledge you will not only be better able to guard your own health, but you will also know how

to safeguard your neighbor's health and thereby make your neighborhood, town, or city a better place in which to live.

Most of the diseases which attack you spread from one person to another. They are called *communicable diseases*, or *contagious* diseases, that is, diseases which may be passed on, or communicated, to others. Perhaps you have "caught" a cold or taken some other sickness from your playmates; similarly, you may have passed on such disease to your friends. Carelessness and thoughtlessness, or ignorance about the cause of disease and how it is spread, are not excusable, for we know today how to prevent the dangers of most communicable diseases.

Underwood and Underwood

Fig. 169. Louis Pasteur

Discoverer of the germ nature of disease, he holds the gratitude of all mankind.

For centuries men lived in ignorance of the causes of communicable diseases. Often the diseases spread to such extent that thousands of people died in a few weeks or months. Even today such *epidemics* occur. Perhaps you recall or have heard of the terrible epidemic of influenza ("flu") which killed more than a half million persons in 1918. The great loss of lives from such epidemics is, however, becoming less and less since man has learned what causes such diseases and how to guard against them.

Probably all communicable diseases are caused by *germs*, which as you know are very tiny invisible living plants or animals. These germs, on account of their small size, enter our bodies without our knowing it. They were discovered in 1865 by Louis Pasteur, a Frenchman, one of the greatest scientists of all time (Figure 169). His discovery was made while he was examining silkworms in France. He found the little germs in the bodies of the worms which became sick,

or died. Later he and other scientists studied the causes of disease in other animals and in man. As a result of these wonderful studies it has been proved that there are many kinds of germs. Those which cause disease are called *pathogenic*, which means "sorrow-producing." Each of the various communicable diseases is very likely caused by a different pathogenic germ, which may be communicated from one person to another.

Fig. 170. A Dangerous Playmate

The coughing boy not only has bad manners, but may spread disease to his friends by means of the spray from his mouth.

As soon as the cause of a disease is known, scientists can study how to treat the disease and how to keep it from spreading. Having thus studied the different disease germs which are known at the present time, they have found many ways in which these are spread. One of the most common ways is through contact with clothing or articles touched by a sick person. Thus, handkerchiefs, bed-clothes, pencils, fruit, candy, drinking cups, and clothing may act as germ carriers. Coughing and sneezing also spread germs which travel on the small droplets of water thrown from the nose or mouth (Figure 170). Many animals act as carriers. Among these are flies, mosquitoes, lice, dogs, and human beings. Still other common sources of disease germs are impure water and impure food. Later you will learn of other carriers, and find that not all kinds of germs are spread in the same way.

The knowledge of the means of spreading disease suggests to you various ways to prevent taking a disease from your neighbor, or passing it on to others. The most important

method of prevention has been studied in Unit V, that is, keeping physically fit. This is the best insurance against germs. Other methods of preventing disease are: (1) to avoid handling objects belonging to sick persons (Figure 171); (2) to avoid persons who cough or sneeze, and to protect others from your coughs and sneezes (Figure 172); (3) to ventilate your rooms well, for some diseases may be spread in the air; (4) to *disinfect*, or cleanse from germs, all clothing and articles touched by a person recovering from a communicable disease; (5) to protect your food from the dangerous organisms; (6) to be sure that your water supply is pure; and (7) to heed the advice of nurses, doctors, and others who have become expert by experience and study. You can perhaps add many more ways to this list.

Fig. 171. Not a Friendly Act
Suppose one of the children is coming down with diphtheria. What poor judgment! What suffering might follow!

While an ounce of prevention is worth more than a pound of cure, we do not always avoid disease, and must, therefore, suffer sickness at times. Even though the body has in it certain materials which may kill the germs, it is not always successful in its fight against these invisible enemies. If you are unfortunate enough to catch a disease, it becomes your duty to receive the proper medical attention and to do everything which you can to protect others from your sickness. You should follow the advice of doctors and boards of health. They have made a careful study of ways of caring for and

Courtesy Chicago Municipal Tuberculosis Sanitarium

Fig. 172. The Criminal
Anyone should be as horrified as the man with glasses is.

treating the human body to cure it and to protect it against the ravages of disease. Medical treatment, quarantine, and other safeguards are the result of scientific study by thousands of trained physicians and scientists.

Above all you should avoid using patent medicines, and refuse to consult "quack" doctors. Thousands and thousands of dollars are foolishly spent every day for these two kinds of frauds. Not only do they usually fail to cure sick people, but, what is worse, they do people such harm that it becomes much more difficult for good doctors to repair the damage done and cure the patient.

PROBLEM 1: HOW DO GERMS MAKE US SICK?

Some germs are plants. The plant germs are called bacteria. Each bacterium is made of a single cell, so small that

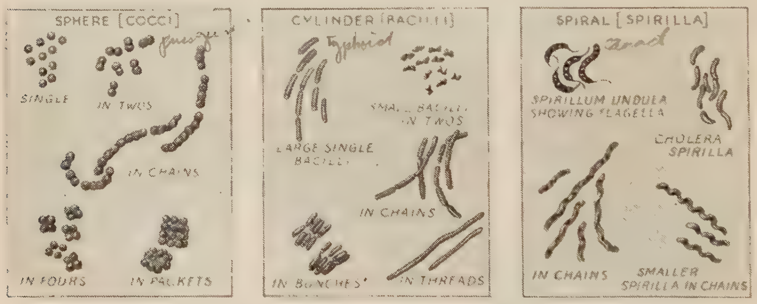


Fig. 173. Shapes of Bacteria

it would require thousands of them to make a row one inch long. Each kind of bacteria is different from every other kind in its appearance and in its action. When seen under the microscope, different bacteria appear in three shapes, as shown in Figure 173. You should realize that there is a great variety of bacteria, not all of which are injurious or dangerous. Many, like those which help to make the soil a better home for plants and those which destroy refuse by decay, are helpful to man. Others are harmless. Still others, the

pathogenic bacteria, are our worst enemies. It is these pathogenic bacteria which cause such contagious diseases as diphtheria, tuberculosis, measles, and typhoid fever.

Animal germs also cause sickness. The animal organisms which cause disease are not so common as bacteria. These animal germs are one-celled and so much like bacteria that it is very hard to tell the difference between them (Figure 174). Several common diseases are caused by them, including dysentery, malarial fever, and sleeping sickness.

Fig. 174. A Malarial Parasite

No. (1) shows how the parasites develop in oöcysts on the outside of the mosquito's stomach. No. (2) shows the many sporozoites within a single oöcyst. In No. (3) one of the red-blood corpuscles has been invaded by a malarial parasite. Here it divides into many sections as shown in No. (4), breaking the wall of the red corpuscle. The new parasites and the poisons, No. (5), enter the blood stream.

Germs are parasites and produce poisons. Any plant or animal which lives in the body of another living thing and takes its food from that living thing is known as a *parasite*. The living thing which furnishes the food is the *host*. The most dangerous of the animal and plant parasites are the pathogenic germs.

Under favorable conditions germs grow very rapidly. If the body does not throw them off, or is not in good enough physical condition to keep them from growing, they begin to get larger. In a short time they divide into two cells in the same way that other cells do (see Figure 73, page 84). Then the two may grow and produce four. Thus, if a single

germ gets into the body and divides into two new germs in a half hour and these continue to multiply at the same rate, there may be formed over sixteen million germs in a half day. During their growth they attack different parts of the body, feeding upon the body cells and producing poisons called *toxins.* In many cases these toxins get into the blood and cause general sickness. Such general poisoning is called *toxœmia.* Sometimes the toxins remain in certain parts and cause only local swelling, redness, and pain, as in some cases of sore throat or in boils.

If the body does not conquer the germs, they continue to multiply and their poisons are produced in great quantity. These toxins first produce certain *symptoms,* or signs, such as a tired feeling, pain, headache, or fever. It is by the study of these symptoms that the doctor is usually able to *diagnose,* or identify, a disease. Often the place where the germs enter the body, such as the nose, throat, or a cut, becomes red, or *inflamed.* If the sickness or infection continues, more and more poisons are formed, and cause severe illness. In cases of local infections the germs may form *pus,* as in boils or abscesses. If the body is finally able to overcome the germs and their poisons, the body becomes well, but if the poisons are produced in such great quantity that the body cannot successfully combat them, death results.

Exercise 1. Name the diseases you have had, and following each, state the symptoms which led you and the doctor to know what the disease was.

Exercise 2. Make a class survey and enter your results in a table which shows the different communicable diseases members of the class have had and how many have had each disease. Which are the most common diseases for your group?

Exercise 3. A single typhoid germ in a glass of water may make you seriously ill. How is this possible?

Exercise 4. Calculate the possible number of germs produced in 12 hours by a single germ. Compare your results with the number for a half a day stated in this problem.

PROBLEM 2: HOW ARE GERMS SPREAD?

Every contagious disease is caused by a particular kind of germ coming from someone who has that disease. In some way the germ must be transferred or communicated to the person who becomes sick. Let us see more clearly how these dangerous parasites are spread, so that you can better understand how to avoid them.

Experiment 48: How may germs be spread?

Prepare several "bacteria gardens," or "cultures," as follows: Obtain several small round dishes or pans and an equal number of larger dishes which may act as covers for the smaller dishes. (Use petri-dishes and covers if available.) Place all of the dishes in clean water and boil the water for an hour. In the meantime place about four ounces of gelatine (used for making jello) in a quart of water. Add one-half ounce of beef extract or about a half pint of rich beef broth, one-half ounce of peptone (this is not absolutely necessary), a pinch of salt, and a pinch of baking soda. Heat the mixture until the gelatine is dissolved and the liquid is clear. Remove the dishes from the hot water and immediately pour enough of the hot culture liquid into each of the small dishes to make a thin layer on the bottom of the dish. Be sure to rest the dishes on a level surface. Cover the dishes with the larger dishes turned upside down. When the gelatine has cooled and hardened proceed as follows:

1. Open the first dish for a half-hour to allow the air to come in contact with the culture; then cover.
2. Open the second dish for only a moment and cough into it; then cover.
3. Open the third dish and pour a few drops of drinking water on the gelatine, spreading it around by shaking the dish; then cover.
4. Open the fourth dish and rub your fingers across the culture; then cover.
5. Leave the fifth dish covered.

Keep all dishes in a warm place at about 70° or 80°F. for two or three days and then examine the "gardens." If bacteria have

entered, they will grow and produce white or yellow spots, as shown in Figures 175, 176, and 177. Each bacterium grows into thousands, which make one of these little spots. The fifth dish will show no spots (Figure 178). What conclusions to the question of the experiment do you reach?

Note: If the gelatine cultures cannot be made, you can use slices of potato. Wash the potato, slice it into pieces about one-quarter inch thick, and place these in saucers or dishes. Steam the saucers and potato slices for a half hour; then remove and cover immediately with larger dishes. When the dishes and potato are cool, proceed as directed with the hardened gelatine cultures.

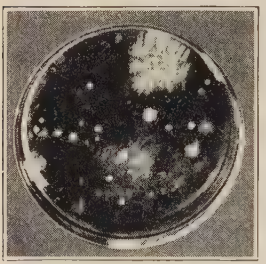


Fig. 175. Petri-Dish Culture

The cover was removed for 20 minutes. The large snow-like patch is a mold growth; the small spots are colonies of bacteria.

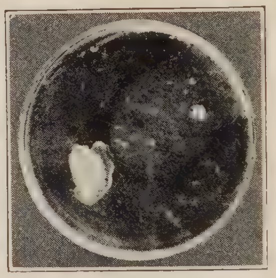


Fig. 176. Petri-Dish Culture

The bright part, which looks like a finger-print, shows where a few drops of water were spread. There are many small colonies of bacteria here.

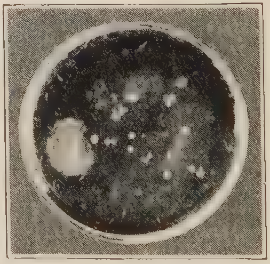


Fig. 177. Petri-Dish Culture

Someone rubbed his fingers across the culture; he thought his hands were clean!

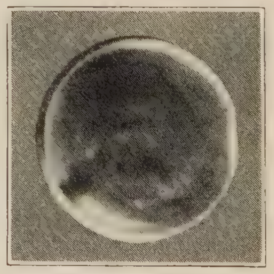


Fig. 178. Petri-Dish Culture

The lid of this dish was not removed; there are no colonies of bacteria to be seen.

Germs are spread by the contact method. One very common method of spreading germs is by contact with sick persons

or with objects touched by them. Thus, kissing sick persons is a dangerous practice; tuberculosis, diphtheria, measles and scarlet fever are but a few of many diseases spread by direct contact. The kinds of objects which may spread disease are so many that only a few will be named: the common drinking cup (Figure 179), handkerchiefs, bed-clothing, razors, eating utensils, dental instruments, towels, toilet seats, bathtubs, pencils, candy, and fruit.

Spitting should also be mentioned in this connection. A person who has tuberculosis, for example, may spit on the sidewalk or in the washbowl. Millions of dangerous germs may be present in the *sputum*. Later this sputum may come in contact with shoes, clothing, or the hands, and find its way into the body of another person.

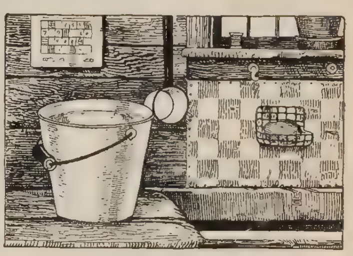


Fig. 179. The Common Drinking-Dipper

Many diseases have been spread by this apparently clean dipper.

This method of transferring disease by contact is made still more dangerous by the fact that persons who are apparently in good health may be "germ carriers." Thus a person may have completely recovered from diphtheria or typhoid fever, or he may never have come down with the disease at all, and yet have the germs in his body. He may spread the disease by handling foods or by any of the above-mentioned ways. It is a fact that a certain cook in New York City, called "Typhoid Mary," who was not sick herself, caused over twenty cases of typhoid before she was discovered. Then, after having agreed never to be a cook again, she did not keep her promise, and a few years later caused many more cases of typhoid in a hospital where she went to work.

Coughing and sneezing spread germs. With each cough or sneeze numerous small invisible drops of water from the linings of the nose and mouth are thrown into the air, as shown

in Figures 170 and 172. Even in speaking these droplets are thrown out. If a person is sick or is a germ carrier, there is great danger that germs will be carried on the droplets.

You might think that all air is dangerous because it carries disease germs. This is not so, because the germs find it hard to live in dry air and sunshine. Fortunately for all of us most of the pathogenic germs are not so hardy as many other germs, and they are soon destroyed outside the body. Nevertheless there is some danger in dusty air. Dust in the air and soil may, for example, carry the tetanus germ, which causes lockjaw.

Food and water are germ spreaders. You recall (see page 102) that food furnishes germs a good home. Milk, vegetables, and oysters may carry typhoid, cholera, and other disease germs in great numbers if infected during handling. And remember that "human disease carriers" may handle the food. Uncovered food is particularly dangerous (Figure 88, page 106).

Fig. 180. The Filthy Fly and Its Filthy Foot

It isn't the buzz of its wings or the tickling effect of its feet that makes this criminal objectionable.

What has been said about food applies equally well to water, except that germs find it harder to live in water than in food. In fact, the number of germs in water decreases when the water is allowed to stand in open containers exposed to sunlight (see Figure 97, page 116). There is, however, always the danger of typhoid and cholera germs in water.

Certain insects act as carriers of disease germs. Among the germ-carrying insects the principal ones are flies and mosquitoes. The ordinary housefly (Figure 180) is in many

places the most dangerous of all. Its feet, as shown in Figure 180, are very hairy, and as it goes about to all kinds of filth, such as manure, garbage cans, toilets, and impure food, it picks up some of this filth. Later it walks on fruits and other uncovered foods or finds its way into our houses and to the table. As it walks it leaves behind bits of filth containing disease germs. Figure 181 shows what may be seen a few days after a fly is allowed to walk across some jello, which contains food for bacteria. Each spot shows that a bacterium has been left behind and has grown into a colony of thousands. Typhoid fever and smallpox are quite commonly carried by the fly.

Courtesy U. S. Department of Agriculture

Fig. 181. The Fly's Gift

Every time the fly walks on your food it leaves filth behind.

Of the other insect carriers certain kinds of mosquitoes are the most dangerous, although the mosquito most common in our country is practically harmless. Malarial and yellow fever are spread by mosquitoes, each by a particular kind. The malarial germ, an animal parasite (Figure 174), is taken into the mosquito's body when the mosquito bites a person who has the germs in his blood. Then later the mosquito bites another person and may pass the germ into that person's body. Some diseases carried by other insects are: typhus fever by the body louse, relapsing fever by bedbugs, lice, and ticks, and sleeping sickness by the tsetse fly.

The story of disease carriers should, no matter how short, contain a word of praise—a tribute—to those noble men who offered their lives that we might know the cause of disease

and the methods of spreading germs. One case will illustrate the spirit with which true scientists work. In 1900, four doctors were sent to Cuba to study the cause of yellow fever. The disease had killed hundreds of Cubans every year and was attacking our soldiers. These men thought the disease might be due to certain mosquitoes. There was only one way to prove their idea and that was to allow themselves to be bitten by the mosquitoes. Two of the brave doctors took the disease. One recovered after a severe illness, but the other sacrificed his life for the sake of his fellow men (Figure 182). The doctors having called for volunteers to help them, two young men offered themselves. Both came down with the disease and later recovered, but one of them became physically disabled by the experiment. The result of the study was so satisfactory that within two years the disease was under control. It is worth while asking yourself in this connection, "Would I be willing to do what these men did for the sake of other people?" The history of mankind shows many such sacrifices made for the benefit of us all.

Fig. 182. Dr. J. W. Lazear
In 1900, while investigating the cause of yellow fever in Cuba, this brave scientist contracted the disease, allowed it to develop in order that he might better study it, and died as a result.

Exercise 5. Find out the names of as many contagious diseases as you can. List these in a column, and after each, state the ways in which the disease is spread and how the germs enter the body. Thus:

Disease	How Spread	Enters Body
Typhoid	Milk, flies, ice, water	Through the mouth

PROBLEM 3: HOW DOES THE BODY PROTECT ITSELF AGAINST GERMS?

The nose and eyes are the watchdogs of the lungs and mouth. The hairs in the nose and the moisture on the nasal passage stop dust from entering the throat and lungs. (See page 150.) In this way the delicate lung lining is protected, and the disease germs cannot easily find their way into the body. Moreover, the nose expels a liquid which washes out the dust and germs. More important than this, the nose and eyes watch over the mouth, detecting spoiled food by its unnatural odor and appearance. Thus the poisons and bacteria in decayed food, and germs, may be kept from the body.

The skin is a sanitary cover of the body. The skin protects the body from germs by keeping a sanitary cover over the easily infected interior parts. How important this is you may readily realize when you recall that the least cut or bruise of the skin may lead to a serious infection. Also, you may know how very carefully doctors cleanse their hands and instruments in water treated with germ-killing chemicals, *germicides*, before they cut or probe through the skin during an operation.

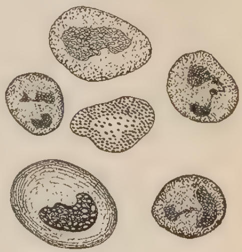


Fig. 183. The Defenders

These little bodies rush to the point of attack by germs and usually conquer the invaders. The white corpuscles are the standing army of the human body.

The body contains an army of disease fighters. Inside the healthy body there is always ready an army to fight the pathogenic germs which gain an entrance. It is said that nearly every adult has had an attack by tuberculosis germs, but that the germs were conquered and left no serious results. This army which serves to protect the body is composed largely of small colorless cells in the blood, called *white corpuscles* (Figure 183). When germs appear in the lungs, intestines, a cut, or in any part of the body, and start to grow, the white corpus-

cles attack the germs and eat them. The germs are killed and changed to harmless materials. There are also formed in the body many chemicals which join forces with the white corpuscles to kill the germs and change the poisons to harmless substances.

While the white corpuscles try to destroy the germs during an attack of disease, there are being formed at the same time by the body cells certain substances called "*anti-bodies*" which destroy the poisons and protect one from further attacks of the same disease. Thus it may be that the body will not be attacked by the same disease for years or even a lifetime. In this condition one is said to be *immune;* that is, he is protected against the disease by the "anti-bodies." These disappear in time, and then the disease may be taken again.

Unfortunately you may not always be in good physical condition or may not use the proper precautions to keep out the germs. In such cases the germs grow rapidly, because there are not enough white corpuscles or anti-bodies to overcome them. You must then get help by giving the body rest or by taking medicines.

Exercise 6. State several reasons why some people are more liable to catch a disease than others.

PROBLEM 4: HOW MAY THE SPREAD OF DISEASE BE DECREASED OR PREVENTED?

The body cannot be depended upon to conquer all disease germs which may enter it. Everyone must, therefore, guard against the spread of these enemies of happiness and health.

Guard against the contact method of spreading disease. Cleanliness and care in our contact with sick persons or with objects touched by them is one method which everyone can use to decrease the spread of disease. If you only stop to think, you will realize that no sensible person would put another's pencil in his mouth, eat of the same candy or other food, bathe in a dirty bath tub, use an unclean toilet seat,

Courtesy American Red Cross

Fig. 184. A Well-Equipped Sick-Room in the Home

Simple furnishings and a bare floor make for cleanliness. The curtains are so arranged as not to exclude fresh air. Why is the bed supported on boxes?

sleep on bed-clothes which were used by a sick person and not disinfected, use a dirty handkerchief or roller towel, or follow numerous similar careless and dangerous practices.

Proper regard for the ones about us is one of the easiest and most successful ways to keep germs from spreading. Even before you come down with a communicable disease, you can know that you are becoming sick. Coughing or sneezing, sore throat, fever, headache, vomiting, diarrhea, breaking out with a rash, feeling tired and worthless, and having chills are some of the symptoms that you may be taking on or have taken a disease. In such cases it is your duty to stay in your room and call a doctor. To go out and be with other boys and girls is most unfair.

Sick people should be kept away from others, and the greatest care in handling objects which they touch must be practiced (Figure 184). It is wise for one who attends a sick person

to wear a slip-over gown which may be left in the sick-room. The hands should be carefully washed on leaving the room. Paper handkerchiefs and paper bags, which may later be burned, should be used as receptacles for discharges from the nose and mouth. Basins and other necessary metal or porcelain vessels should be kept clean and sanitary by washing in water containing germ-killing chemicals. And upon the recovery of one who has a contagious disease, all clothes and articles in the room should be disinfected, or *sterilized*. Heat, water which contains germicides, fumigating gases, sunshine, and fresh air are the important agents which should be used to make the room and the articles safe. A good doctor will always give proper directions for the care of the sick and of the sick-room. You can also get such directions by writing to the board of health of your city or state.

Courtesy Minnesota Board of Health

Fig. 185. A Sanitary Drinking-Fountain

Fig. 186. Sanitary Paraffined-Paper Cups

Exercise 7. Make a list of the careless practices by which diseases may be communicated through contact with sick persons or with things touched by such persons. From your own experience add after each practice such diseases as you know have been spread by that method. Thus:

Careless Practice	Diseases
Using another's handkerchief	Tuberculosis
Using another's pencil	Diphtheria

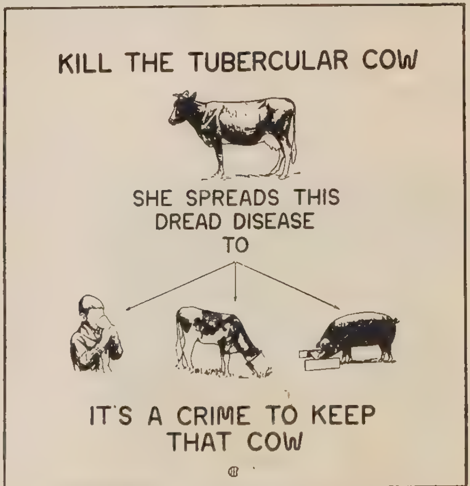
The method of protection against coughing, sneezing, and spitting is clear to any thinking person.

Exercise 8. Give three things which you can do to prevent spreading germs by your coughing, sneezing, or spitting.

Exercise 9. State three or four sensible things which you can do to avoid catching a disease from people who are careless in coughing, sneezing, and spitting.

Exercise 10. Why are the drinking-fountain (Figure 185), and the cups (Figure 186), more sanitary, or hygienic, than the dipper in Figure 179?

Milk is one of the most dangerous carriers of disease. Typhoid fever and diarrhea, especially, have often been spread by milk. Many cases of diphtheria, tuberculosis, scarlet fever, and sore throat have also been traced to the milk supply. Milk furnishes excellent food for bacteria, and when the temperature is favorable they multiply rapidly in it. You can see therefore how important it is that milk be kept at the proper temperature and carefully handled.

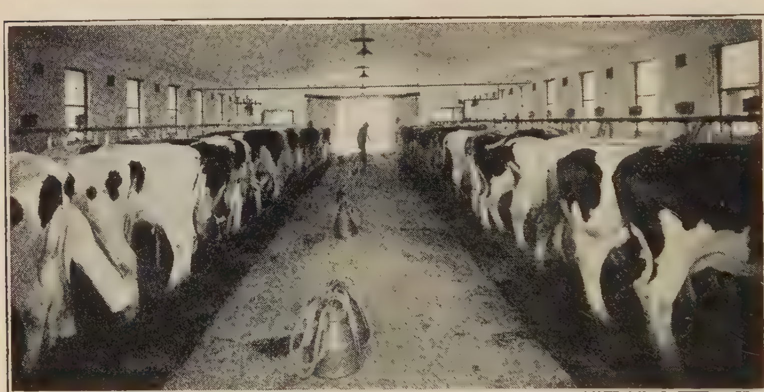


Courtesy International Harvester Co.

Fig. 187. The Tubercular Cow

All milk should come from healthy cows. Tuberculosis is very common among cattle, and the germs may easily find their way into the milk supply if sanitary conditions are not maintained in the barns. All cattle should be tested for tuberculosis. Thus dangerous sources of milk may be done away with (Figure 187).

The milk supply should be carefully protected during handling. Stables need particular care (Figure 188). Cows should

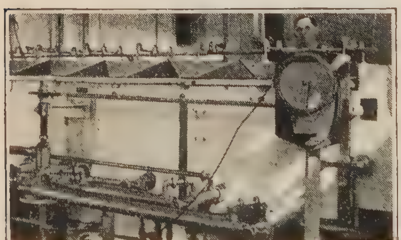


Ewing Galloway

Fig. 188. A Model Dairy Barn

Well lighted, well ventilated, and clean stables make cows happy and lessen the danger of disease.

be kept clean. Bits of manure, dirty hands, and unclean pails and cans carry germs into the milk. It is probably true that typhoid germs find their way into milk more commonly from water used to wash or rinse the cans than from any other source. Men who handle the milk must not only be well, but they must also not be "human carriers" of disease. There is one instance on record where 400 cases of typhoid fever were caused by milk handled by a man who had not had the disease for over forty years. In another instance a milk-man who had sore throat caused over 200 cases of sore throat among his customers.

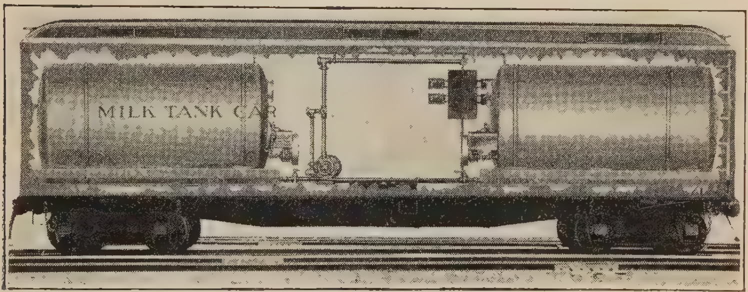


Ewing Galloway

Fig. 189. Pasteurizing Milk

The large vats contain the milk. The dial is on a thermometer which records the temperature. The pasteurized milk goes to the bottling machine (Figure 191) through clean pipes.

When milk is shipped into cities, it must be protected against bacteria (Figure 190). To kill any germs present, pasteurization is used (Figure 189). You remember this process from

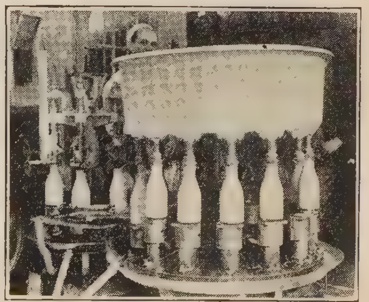


Courtesy Pfaudler Co.

Fig. 190. A Sanitary Milk Car

The modern way of shipping milk makes use of large glass-lined steel tanks constructed like a vacuum bottle, keeping the milk cool and clean.

Unit III (page 107). In the larger cities all men who handle milk are carefully examined. The pasteurization is also made to conform to certain requirements. The process of heating milk to 144°F. for 30 minutes is the most satisfactory one. (See page 107.) This kills all pathogenic bacteria and many of the other hardier ones. The milk, after it has been pasteurized, is bottled by machines (Figure 191).



Ewing Galloway

Fig. 191. A Milk Bottler

No human hands touch the milk.

In the home equal care must be practiced. Thousands and thousands of babies die because their milk bottles and the rubber nipples are not kept clean. Being a baby is the most dangerous life in the world, simply because older people are careless. And milk is one of the greatest sources of danger.

Bottles are not kept in the refrigerator, caps are removed and not replaced, glasses are not cleaned properly, hands are not washed before handling the bottles, the mouths of bottles are not kept clean, and in many other ways it is made possible for germs to get into the baby's milk.

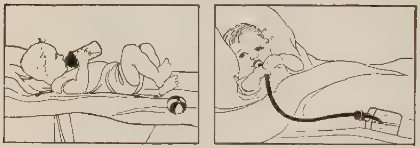


Fig. 192. Baby's Milk Bottle

Experiment 49: How may milk be contaminated?

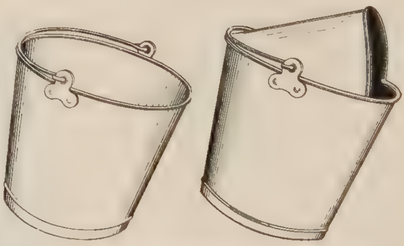
(*a*) Pasteurize a half-pint of raw milk, or use a small bottle of pasteurized milk.

(*b*) Sterilize a test tube in boiling water for a half-hour, or by heating in a gas flame. Pour some of the pasteurized milk into the tube and stopper it with cotton.

(*c*) Pour milk into a second sterilized test tube; allow the tube to stand unstoppered for a half-hour; then stopper it.

(*d*) Wash a third test tube with ordinary cold water; without drying the tube, add milk and stopper it with cotton.

(*e*) Examine the milk from day to day to note any changes, such as curdling, becoming watery, and producing bad odors. Do not remove the stoppers. What are your conclusions to the question asked in the experiment title?



Courtesy International Harvester Co.

Fig. 193. Milk Pails

Exercise 11. Which bottle (Figure 192) do you think is more sanitary? Why?

Exercise 12. Which milk pail (Figure 193) is more sanitary? Why?

Exercise 13. State as many ways as you can which help to eliminate diseases that may be spread by milk. For information in addition to that contained in the text consult your milk dealer or write to the city or state board of health.

Protect yourself against other impure foods. Raw oysters are always a source of danger, for they may come from water which contains sewage or they may spoil through improper handling. One case on record shows that oysters from polluted water near Long Island, New York, were shipped to several cities and within a short time caused fifteen cases of typhoid fever and nearly a hundred cases of diarrhea. Nearly every one who attended a banquet in one of the towns where the oysters were served became ill. Such danger can be reduced to a great extent by keeping a careful check on the water from which oysters are taken. It is equally necessary that they be packed immediately, that they be kept covered and cold during shipping, and that they be served while they are fresh.

Meats, fruits, and vegetables must all be considered as possible germ carriers. They may have been kept in unclean and uncovered places where germs could get on them. Then if they are not thoroughly cooked or washed, the germs may get into our bodies. Foods of all kinds should always be covered (see Figure 87, page 105). Perhaps the greatest danger lies in the preparation of food for the table by those who fail to keep their hands clean and by disease carriers. You have learned in the case of "Typhoid Mary" but one of many instances where these people spread disease and bring sorrow to others. Unfortunately "carriers" cannot always be detected. There should, however, be laws, as there are in some cities, which require that cooks and waiters in public eating places be regularly examined. And in the home every precaution should be taken by one who has had a communicable disease to protect members of his family and his guests from impure food. The best way to do this is to have regular physical examinations and to keep the hands especially clean when handling food.

Exercise 14. Enumerate the important methods which should be used to insure that foods, other than milk, come to your table pure and safe.

Exercise 15. Make a survey of the grocery stores, meat markets, fruit and vegetable stands in your neighborhood, and your kitchen and refrigerator to find sources of danger to your food. Make a written report on your investigation. If you find serious violations outside the home, consult your teacher about writing a letter to the board of health explaining what you found.

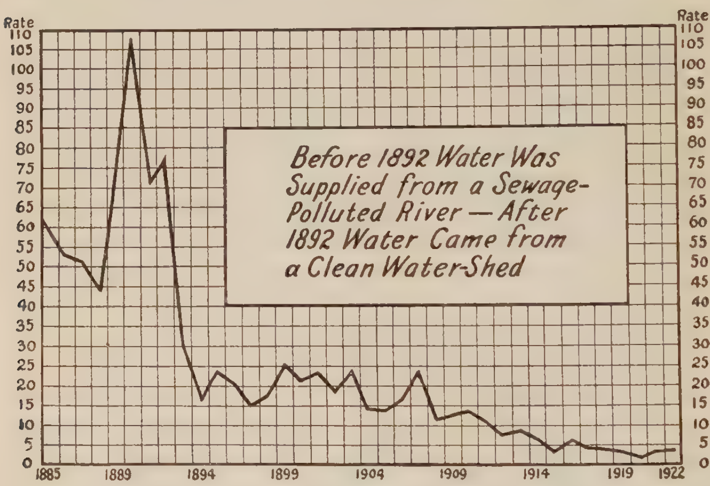


Fig. 194. Control of Typhoid Fever in Newark, New Jersey

A pure-water supply has reduced the death-rate from 78 per 100,000 in 1892 to 3 per 100,000 in 1922.

Prevent water-borne diseases. Practically every large city in the world finds it necessary to expend much money to keep its water supply from becoming polluted, and to purify it. Similarly, in the country every precaution against water-borne diseases should be practiced. There are many cases known where epidemics of typhoid fever have been caused by impure water. Figure 194 shows how the death-rate from water-borne disease can be reduced by providing a pure water supply. Figure 195 shows the effect on the typhoid death-rate of such sanitary methods as sewage disposal and pasteurization of milk.

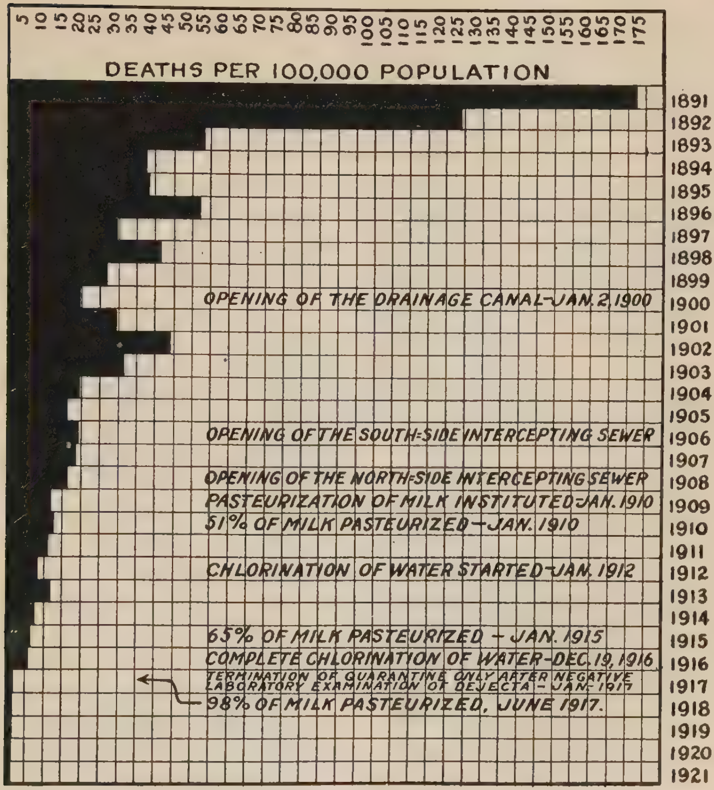


Fig. 195. Typhoid Death-Rate in Chicago (1890-1922)

Serious epidemics raised the death-rate in 1891, 1892, 1901, 1902, and 1903. Note the different factors which have helped reduce typhoid in Chicago.

Exercise 16. Refer to Unit IV and enumerate the different methods used to protect people from the disease germs in water. Following each indicate how the method protects us. Thus:

METHOD	PROTECTS US BY
Proper construction of shallow wells, etc.	Keeping germs out of the water

Fight the filthy fly. Manure piles, garbage cans, open toilets, rubbish piles, and sewage are the joys of a fly's life. In these the fly finds its appetizing food and a most desirable place to raise its young. Here the female fly may lay from 120 to 150 eggs at a single time. Four or five such batches may be laid during a season. Under proper conditions of warmth and moisture each of these eggs grows into a *larva,* or small white worm, in less than a day; the larva, or maggot, becomes a *pupa* after about five days; the pupa in turn grows into a fly

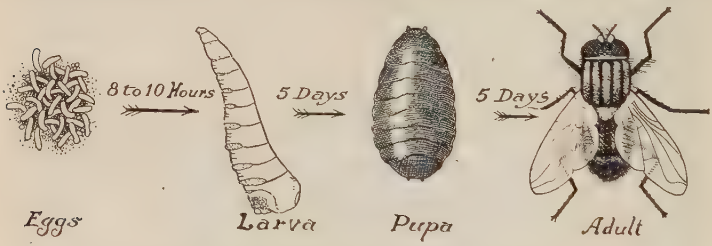


Fig. 196. Four Stages in the Life of the Fly

You see by examining the figure that a fly egg may develop into an adult fly in about 11 days.

in five or six more days (Figure 196). Thus within a season a single fly may produce over 500 new flies, each of which endangers our lives. And as each female fly becomes two weeks old, she may lay eggs and so produce still more. Thus a single fly in April may multiply and bring into the world 6,000,000,000,000 flies by September.

It is clear that the most effective way to fight the fly is to prevent the fly from multiplying. Every one of the above-mentioned homes of the fly can be treated with chemicals which kill the fly eggs and which keep the fly from spending its time in such places. Thus, borax may be spread on manure, and lime or bleaching powder may be placed in garbage, open toilets, rubbish piles, and sewage. Garbage cans can be kept clean and covered, open toilets may be eliminated by building septic tanks, or they may be protected by screens,

rubbish piles can be burned or hauled away, and sewage can be mixed with water in septic tanks. (See page 133.)

A second method of fighting the fly is to catch and kill the adult fly whenever possible. Sticky paper, poisons, fly traps, and fly swatters (Figure 197) are among the most effective methods. You should bear in mind that for every adult female fly killed, you are really keeping millions of flies from coming into the world. This is especially true early in the spring. There is in these methods only one danger which you must remember, and that is the danger of some fly poisons to children and animals.

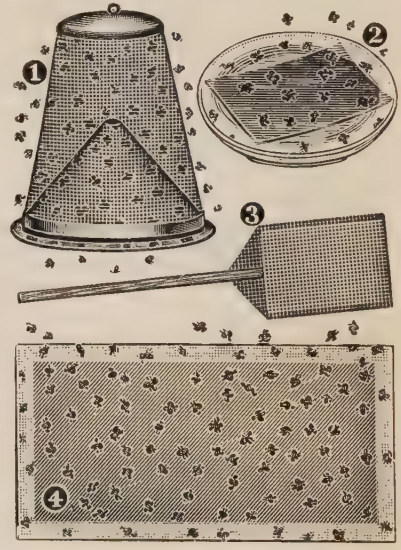


Fig. 197. Fighting the Fly

(1) Fly trap, (2) poison, (3) swatter, (4) sticky paper.

The third method of guarding against the house fly is to keep it away from food materials and away from our bodies. How important this is can be seen from the fact that an examination of the feet of more than 100 flies showed that each fly carried over 1,000,000 germs. These germs may enter the body with the food we eat or when the fly comes in direct contact with the mouth or an open sore. Flies in the house are, of course, particularly dangerous when a member of the family has a communicable disease.

Exercise 17. Make a survey of your community to discover the presence of breeding places for flies. Report your findings. Organize a school or a community squad to rid the community of flies in the spring of the year.

Exercise 18. Why should the baby be protected from flies when left to sleep in the open air? How can this best be done?

Exercise 19. How can you help to keep flies from your house and from your food supply? Mention the different ways.

Eliminate the mosquito. It is stated that malarial fever, spread by one kind of mosquito, causes one-half of all the deaths in the world. In some tropical regions, such as India,

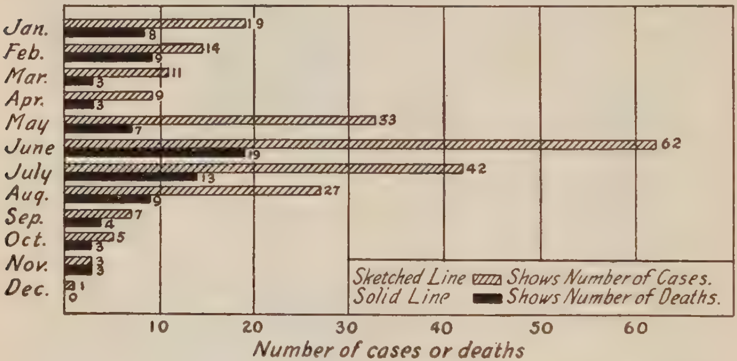


Fig. 198. Control of Yellow Fever in the Panama Canal Zone

In June, 1905, the United States took control of the Canal Zone. By destroying the mosquito the death-rate was reduced, as shown in this figure.

millions of people have died of malaria in a single year. In our southern states there were from two to three million cases a year before scientists learned what caused the disease.

Yellow fever, spread by another kind of mosquito, has been until recent years very common in certain parts of America. In New Orleans, for example, nearly 8000 people died in 1853, and over 4000 in 1878. You probably recall from your geography how the United States Government succeeded in constructing the Panama Canal only because Colonel Gorgas of the Army Medical Department and his helpers went to the Canal Zone before the laborers arrived, and eliminated much of the danger from both yellow and malarial fever (Figure 198).

The principal methods by which the danger from all kinds of mosquitoes can be controlled may be considered under three heads: (*a*) preventing their growth, (*b*) killing the larvæ and the pupæ (Figure 199), and (*c*) protecting ourselves against the full-grown mosquito. The prevention of the growth of mosquitoes may be brought about by protecting cisterns, cesspools, rain barrels, sinks, and water pails by screens or covers, by draining and clearing swampy regions, by burying tin cans and other unnecessary receptacles in which water may stand, by avoiding throwing waste water where it will stand on the ground for some time, by keeping the channels of streams clear of grass and weeds, and by draining standing pools along the banks (Figure 200). Killing the larvæ and the pupæ may be done by spreading oil on the water every few weeks in the spring (Figure 201) or by stocking any ponds with fish and frogs. The oil floats in a thin layer over the water. The larvæ and pupæ, which must breathe, cannot get air because the oil fills their breathing tubes. Moreover, the adult mosquitoes cannot rest on the oily surface, and therefore cannot lay their eggs. Fish and frogs feed on the larvæ or wrigglers. The

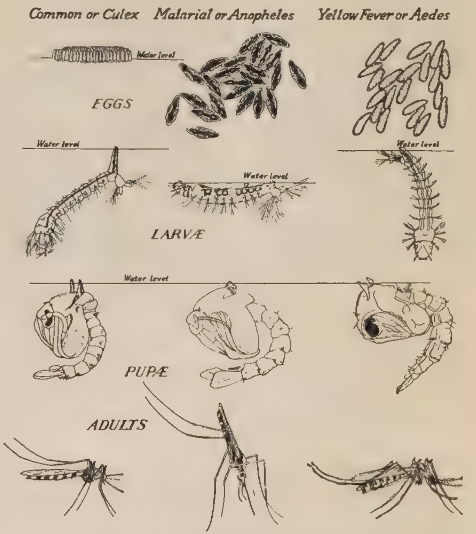


Fig. 199. Life Stages of Mosquitoes

Each of these three kinds of mosquitoes develops through the four stages: egg, larva, pupa, adult. In the larva and pupa stages they breathe through the breathing tubes which extend upward above the surface of the water.

remedies against the adult mosquito include screening our houses to keep mosquitoes out, *fumigating*, or disinfecting, to kill any mosquitoes which have rested in the house during the winter or have gained entrance later, and keeping any one who is sick with malaria or yellow fever in a carefully screened room so that no malarial or yellow-fever mosquitoes may enter and get a new supply of germs to be passed on to others.

Fig. 200. Destroying Breeding Places of Mosquitoes

Mosquitoes breed rapidly in places like that shown at the left. When the grass and bushes are removed and the stagnant water drained away, they will not lay eggs there.

Exercise 20. Make a survey of your community and report what you can do to eliminate the growth of mosquitoes in the spring of the year.

Exercise 21. Make a complete outline of your knowledge about "Mosquitoes as Carriers of Disease."

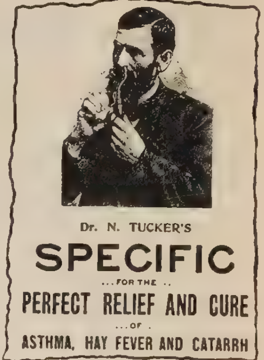
Courtesy U. S. Department of Agriculture

Fig. 201. Fighting Mosquitoes With Oil

Oil is being sprinkled in the roadside ditches where mosquitoes find breeding places.

Control other disease carriers. Several other living carriers or causes of disease are worth our considering, although not so important in most places as the fly and mosquito. In the fourteenth century

approximately twenty-five million people died in Europe of the terrible Bubonic plague which was spread by rats and fleas. Typhus fever spread by lice has caused many serious epidemics, and during the World War killed many soldiers. "Mad" dogs have bitten many people and thereby spread the germs known as rabies, which cause hydrophobia. Then there are also certain worms which get into our bodies and rob us of our energy and life. Among these are the hook-worm, so common in regions where human wastes are not properly disposed of and where people go barefoot, the trichina (see Figure 83, page 102), present in uncooked pork, and the flatworm and the tapeworm, present in uncooked pork or beef.



Courtesy Am. Med. Ass'n.

Fig. 202
A Patent-Medicine Advertisement

This so-called cure contained cocaine, a habit-forming drug. It was not a specific cure for asthma or hay fever.

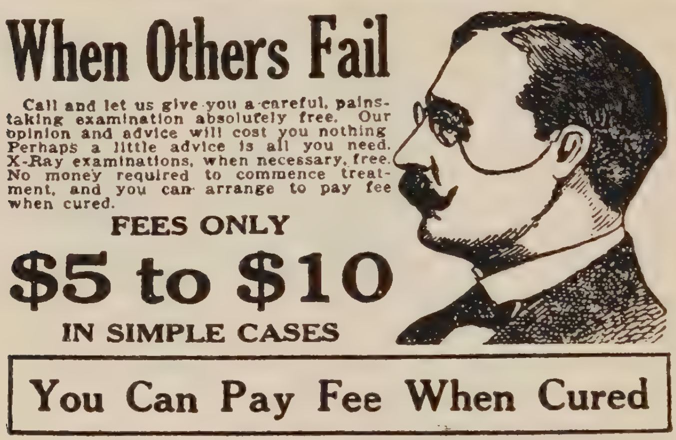
Exercise 22. Make an outline of all the principal ways mentioned in this problem in which disease may be spread.

PROBLEM 5: HOW CAN YOU HELP THE BODY PROTECT ITSELF AGAINST DISEASES?

A good doctor helps the body protect itself. The greatest help in the treatment of the sick body comes through the advice and care of a good doctor. Guarding the health of human beings is his business. He has studied the human machine, its workings and its ailments. The first suggestion in helping the body is, therefore, not to try to treat a disease yourself, nor to call on a "quack" or "fake" doctor, nor to use patent medicines and "dope" recommended by untrained persons (Figures 202 and 203). You will, if you are sensible call a doctor whose training has been the best and whose character is known and recognized to be above criticism. And you should

call him early before any disease gets a firm hold on you.

You should realize, also, the value of depending on the doctor and the dentist even when you are well. By regular



Courtesy American Medical Association

Fig. 203. An Advertisement of a Quack Doctor

A reputable doctor does not advertise in this way; his reputation spreads through his service to mankind.

examinations these trained experts may save you days of suffering. How the doctor determines what help the body needs in case of sickness and what medicine, if any, should be given, is too difficult for us to understand at this time.

Immunity is aided by vaccines and antitoxins. Rest, good air, exercise, proper diet, and medicines are not the only means of helping the body fight disease germs. There are two other important ways which may be used to assist the white corpuscles and the chemical substances within the body in their fight against germs. Thus, certain *vaccines* and *antitoxic sera* may be injected into the body to strengthen or reinforce the army of disease fighters and to make the body immune.

The use of vaccines and their value may be illustrated in connection with smallpox. Dr. Edward Jenner, an English physician, in 1798 found that persons who were vaccinated

did not take smallpox. He obtained the vaccine from the swellings on cows that had cowpox, a disease something like smallpox. All that was necessary was to place on scratches in the skin of persons some of the watery material, or *lymph*, from the swellings. As a result of his work and that of others the death-rate from smallpox has been greatly reduced, and the disease can be practically eliminated if people are regularly vaccinated.

Today the vaccine is prepared in very pure form and so applied to the human body that there is little danger of infection by other germs. The records of a certain city show 3811 cases of smallpox over a certain period of years. One hundred seventy-one of these persons died, but among these there was not a single person who had been properly vaccinated. This is direct proof of the value of vaccination. Persons who are properly vaccinated develop a mild form of cowpox. During this mild disease the body manufactures "anti-bodies" which overcome the disease and which remain for years to guard the body against attacks of smallpox. The average length of the immunity as a result of a vaccination is about seven years.

Similar successful vaccination has been carried on against typhoid fever, para-typhoid fever, cholera, and rabies. When any of these vaccines is used, the body begins to manufacture the proper anti-bodies to fight the particular kind of germs. This method of producing immunity results in *active immunity*, for the body itself is active in making the anti-bodies. One illustration will show the great value of vaccination against typhoid fever. Among approximately 100,000 soldiers who took part in the Spanish-American War about 10,000 had serious cases of typhoid and 1500 died. In the World War all soldiers were vaccinated against typhoid and para-typhoid. Out of 4,000,000 soldiers there were only about 300 cases and 23 deaths.

Antitoxins, given for diphtheria, tetanus (lockjaw), scarlet fever and certain other diseases, act in a different way from the

vaccines to produce immunity. The preparation of an antitoxin is well illustrated by the method used in diphtheria. The diphtheria germs are grown in cultures in the laboratory. Here they produce their toxins. These toxins, without any live germs, are injected into healthy horses especially selected for the purpose. At regular periods of a few days each, more and greater doses of toxins are given the horse. Meanwhile his body manufactures more and more antitoxin, until the blood contains large amounts. Some blood is then removed from the horse and from this the serum, or watery part of the blood, is taken. This serum, containing the antitoxin, is then injected into the body of one suffering from diphtheria. If this is done during the first day of attack by the diphtheria germs, the patient is well within a few days. If a patient waits two or three days before taking the antitoxic serum, he does not recover so quickly and certainly. And if he waits still longer, the serum does little good. This method of producing immunity results in *passive immunity*, because the anti-bodies are made outside the human body. Figure 204 shows how the death rate from diphtheria may be reduced by the use of antitoxin.

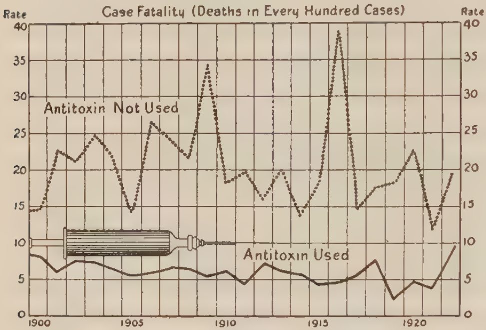


Fig. 204. Control of Diphtheria by Antitoxin

The dotted line shows the death rate for different years in places which did not use antitoxin; the heavy line shows the death rate for places using antitoxin.

Exercise 23. How often should you be vaccinated against smallpox? Explain your answer.

Exercise 24. Explain the differences between a vaccine and an antitoxin.

Exercise 25. Now that you have finished your study of this

unit, write twelve good rules which everybody should follow to avoid contagious diseases. Thus:

RULE 1. Keep in the best possible physical condition by proper sleep, exercise, rest, and avoidance of worry.

RULE 2. Put nothing in your mouth but pure water, pure food, and a clean toothbrush.

Review Exercise on Unit VII. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit VII and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT VII

1. Examine under a microscope the foot of a fly, and make a drawing of it.

2. Dip up a glass of water from a still pool of water in a swampy region. Examine to see if there are any mosquito larvæ (Figure 199). If there are, keep the glass covered with a cloth and watch the larvæ develop into wrigglers and adult mosquitoes.

3. Find out what regulations your state, county, or city has regarding protection of milk supply, water supply, food supply, and other sanitary measures.

4. Persons sometimes "catch a cold" by sitting in a draft, getting wet feet, or not being covered properly during sleep. Explain how this is possible when such "colds" are really caused by germs.

5. Make a survey of your home and its surroundings to find possible ways of spreading disease germs. Make a report of your findings.

6. Explain why nurses and surgeons wear white flowing gowns and cover their mouths and noses in the operating rooms.

UNIT VIII

THE NATURE AND CONTROL OF FIRE

Preliminary Exercises

1. Make a list of things in your room that were made by the use of fire.

2. In what ways would your life be changed if there were no fire?

3. What part does fire play in the manufacture of automobiles and other machines?

4. What is the best method of building a fire out-of-doors?

5. How are fires started and regulated in stoves and furnaces?

6. What is left after wood is burned? What becomes of the wood?

7. Some materials make a large amount of smoke when they burn. How do you explain this?

8. Explain the expression "Fire is a good servant but a bad master."

9. How do you think man first obtained fire?

10. Make as large a list as you can of materials which burn, dividing them into two classes, natural and artificial. ("Artificial" means made by man.) Star the materials which are used for fuels.

11. Explain why air rushes into a fireplace or the drafts of a stove.

THE STORY OF UNIT VIII

We shall never know how man first discovered that fire could be harnessed and made to work for him. His early acquaintance with fire may have come from a blazing forest set on fire by lightning; perhaps it came from a flaming volcano which lighted up the night and poured hot liquid rock and ashes down into the plains below. At first man probably regarded these happenings, or phenomena, of nature with awe or reverence; but soon his natural curiosity must have

triumphed over his fear. He found that fire could be used to cook his food, furnish light and heat for his shelter, and protect him from wild beasts.

Many thousands of years have passed since primitive man first used fire for his simple needs, and with this passage of time, man's knowledge of and dependence upon fire have greatly increased. By its use he separates metals from their ores, he produces steam to run machinery, and he makes the thousand-and-one articles which add to his comfort and efficiency. Can you picture what this world would be without fire?

American Museum of Natural History

Fig. 205. Obtaining Fire by Friction

The upright stick is rotated by the hands. The lower end of the stick is pointed and fits into a small hole in the lower block.

You have often heard how primitive peoples, like the American Indians, obtained fire by rubbing together two sticks of dried wood (Figure 205). The friction of the rubbing surfaces caused enough heat to "set fire" to dry, decaying wood, leaves, or moss, which was placed around the rubbing surfaces. One of the Boy Scout tests is to start a fire by this method. Try it, using hard wood for the upright stick and soft wood for the block.

Our great-great-grandfathers made fire by striking together two materials such as steel and flint. When these materials are struck together, sparks are produced, and these are allowed to fall on easily kindled substances. The old flint-lock musket used this method of firing. The steel hammer struck against a piece of flint, sending a spark into the powder held in the priming cup just below the flint. This powder burned, carrying the fire through a small hole in the barrel of the gun, and

lighted the firing-charge of powder inside the barrel (Figure 206). The modern friction gas-lighter and cigar-lighter (Figure 207) operate in the same manner, a piece of flint being rubbed by a circular piece of steel.

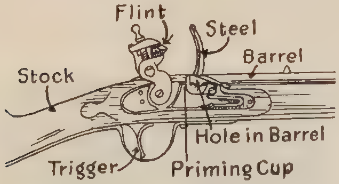


Fig. 206. A Flint-Lock Musket

When the trigger is pulled, the flint strikes the steel, and a spark is sent into the powder in priming cup. The fire gets to the charge in the barrel through a small hole.

It was not until 1827 that the first match which could be lighted by rubbing the tip was invented. This was made possible by discoveries of chemists, who learned more about the nature of fire. Thus the uncertain methods of rubbing sticks together and striking sparks have given way to the match, which can be kindled at any time, at any place, and with very little effort.

If you look around you, you see many materials which cannot be used for a fire, such as stone, soil, glass, brick, and water. Many other materials, such as paper, wood, cloth, bark, and coal, burn readily. Materials which will not burn are said to be *incombustible*, while materials which burn are known as *combustible*. The first requirement for a fire is a combustible material.

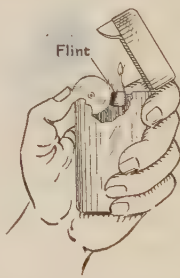


Fig. 207. A Friction Gas-Lighter

The barrel of the lighter is filled with gasoline, which comes up through the wick.

Not all materials which burn are *fuels*. A combustible material is called a fuel if it has three characteristics: (1) it must start to burn at a fairly low temperature in ordinary air and continue to burn as long as the proper amount of air is supplied; (2) it must burn rapidly enough to produce sufficient heat for the use which we wish to make of it; and (3) it must be available in large quantities and at a reasonable cost. If a combustible material lacks any one of these characteristics, it cannot be called a

good fuel. Let us consider some materials, and see if they meet these requirements.

We see at once that wood, coal, gas, and gasoline meet all of the requirements. A material like iron will burn in oxygen, but not in ordinary air. It cannot be classed as a fuel. Paper meets the first requirement, but does not give enough heat for the usual uses of fuels in stoves or furnaces. Many of our hard woods, such as oak, walnut, and mahogany, meet the first two requirements, but their use for furniture and lumber makes them too expensive to be classed as important fuels. What is a good fuel at one time may not, because of the discovery of new fuels or because it becomes scarce, be a good fuel at a later time.

Fig. 208. How to Lay Wood for a Fire

Though a fuel or combustible material is necessary for a fire, there are also other requirements.

It is not always easy to start a fire in the woods or in a stove, even if you have good fire materials. Boy Scouts, Girl Scouts, and Camp Fire Girls know that the real trick of building a fire is in arranging the wood or other fire materials. If the sticks are stacked around the center like the poles of an Indian wigwam (Figure 208) and the fire is started on the side from which the wind comes, a good blaze always results. The spaces between the sticks allow the air to come in and circulate through the wood. Without air the fire "goes out." The second requirement for a fire is, therefore, a continuous supply of air.

When you start a fire, you bring a lighted match to the paper or leaves. Why do the paper or leaves "catch on fire"? The burning match gives off heat. This heat raises the temperature of the paper. The paper finally reaches a certain temperature at which it bursts into flame. This is called the *burning temperature* of the paper. Some materials, like coal and hard wood, have high burning temperatures; that is, they must

be heated to a high temperature before they will burst into flame. Other materials, like paper and corn-cobs, have low burning temperatures. The third requirement is that the material be heated to its burning temperature.

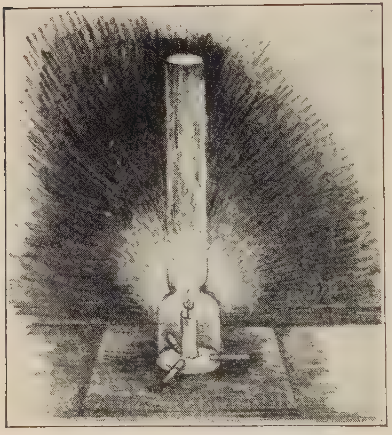


Fig. 209. How a Fire Gets Air

A fire has two outstanding characteristics: first, it always produces heat and light, and second, the material which burns changes to new materials and gradually disappears. In order to understand the nature of fire we must find out the causes which are responsible for these characteristics. For it is only through understanding that we can learn to control and use this wonderful gift of nature.

PROBLEM 1: HOW DOES A FIRE GET AIR?

Convection currents supply a fire with air. When a material burns, fresh air must be constantly supplied. How does the fire do this?

Experiment 50: How does fresh air reach the flame?

(*a*) Place three or four matches at the side of a candle, as shown in Figure 209. Light the candle, place the chimney over it, and cover the top of the chimney. In a short time the candle goes out. Why?

(*b*) Repeat (*a*), but do not cover the top of the chimney. Why does the candle continue to burn?

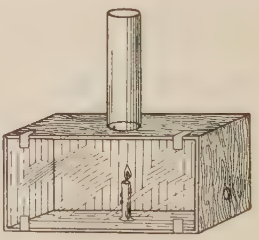


Fig. 210. Apparatus for Experiment 50

The glass front can be fastened to the box with gummed labels.

(*c*) Arrange an apparatus as shown in Figure 210. This is a box fitted with a

glass front. One hole is cut in the top of the box and another in the side near the bottom. A lamp chimney is placed over the hole in the top, and a burning candle is placed inside of the box directly under the hole. Hold a piece of smoking punk-stick or paper over the chimney which stands above the candle. Does the smoke move up or down? Now move the smoking paper or stick to the hole at the side of the box. What happens? This movement of the air caused by differences in temperature is called a *convection current*. Why does a difference in temperature cause a convection current? (See page 57.)

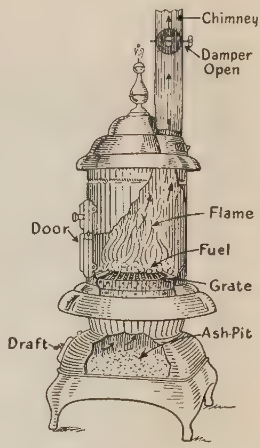


Fig. 211. Sectional View of a Stove

Exercise 1. Make a drawing of the apparatus, and show by small arrows the direction of the air currents through it. On the basis of this experiment and of Experiments 11 and 12, page 57, answer the question, "How does the fire provide its own supply of fresh air?"

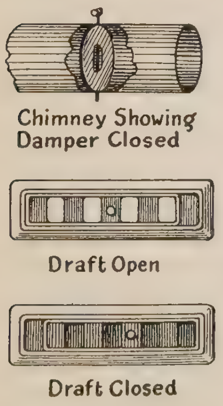
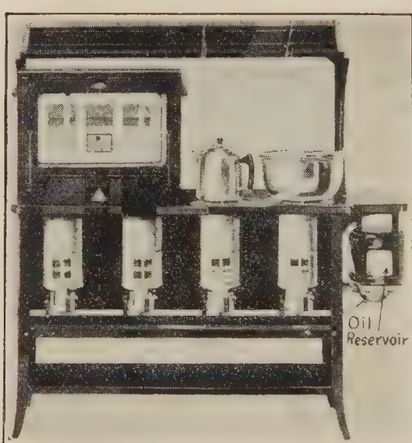


Fig. 212. Drafts and a Damper

The air supply of stoves and furnaces must be regulated. Stoves and furnaces have two devices for regulating the amount of air which passes through them. Near the bottom of the stove are air openings called *drafts* (Figure 212). The size of the openings is regulated by a sliding cover (Figure 212). The draft regulates the amount of air which comes into the stove. A stove-pipe usually carries to the chimney the gases formed in burning. In this pipe a *damper* is placed (Figure 211). The damper is a circular piece of metal which just fits inside the stove-pipe. It is shown closed in Figure 212, and open in Figure 211. When it is open, the gases

and smoke may pass out of the chimney; when partially closed, it prevents the hot gases from escaping up the chimney too rapidly, and thus more heat is given to the room. By adjusting the draft and damper, any desired amount of air can be obtained.



Courtesy Cleveland Metal Products Co.

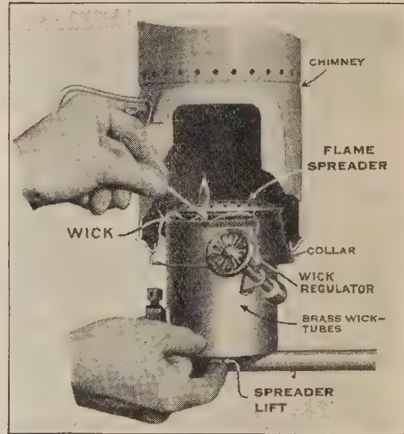
Fig. 213. A Kerosene Stove

Exercise 2. How would you arrange the drafts and damper on a stove when you start the fire? What change would you make after the fire is well started? When you want less heat?

The kerosene stove automatically supplies its air. The main parts of the kerosene cook-stove are the *feed-reservoir*, *feed-pipe*, *burner*, *wick*, and *chimney* (Figures 213 and 214). The reservoir is usually made of glass so that the oil level may always be seen. The oil flows by gravity through the feed-pipe and supplies the different burners. The burner holds the wick in place and is hollow in the center so that air may enter. Air may also enter around the burner on the outside of the wick. At the top of the burner is the *flame-spreader*, which throws the flame outward. The chimney is placed over the burner, and above the chimney is the grate. Except for the flame-spreader, the construction of the kerosene stove is but little different from that of the kerosene lamp.

To put the stove in operation, the reservoir is filled with a good grade of kerosene oil. The kerosene flows by gravity through the feed-pipe and is absorbed by the wick, through which it rises. The flame-spreader is then lifted up and the wick is lighted. When the flame encircles the entire wick, the flame-spreader is lowered and the height of the wick is

adjusted. The amount of heat produced is regulated by the height of the wick, which should never be raised high enough to touch the flame-spreader. The chimney prevents the heat from escaping at the sides, and the difference in weight between the hot air inside the chimney and the cold air outside produces a convection current. The hot air is forced out through the top of the chimney, over which the cooking vessels are placed.



Courtesy Cleveland Metal Products Co.

Fig. 214. Parts of a Kerosene Burner

The feed-pipe carrying oil from the reservoir enters the bottom of the burner.

Exercise 3. Write a set of directions which you would send out with each oil stove if you were selling stoves.

Gas burners require careful adjustment of air. The gas burner is the most satisfactory cooking device. It takes up but little space, burns with little odor, is always ready, leaves no ashes or dirt, is economical, and can be regulated so that the desired amount of heat can be secured.

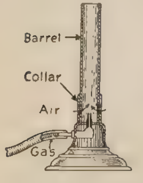


Fig. 215. A Bunsen Burner

In the laboratory the *Bunsen burner* (Figure 215), which uses natural or artificial gas for fuel, is the most frequently used apparatus. It is very similar to the burner used in gas stoves.

Experiment 51: How is the Bunsen burner constructed and how does it operate?

(*a*) Unscrew the *barrel* from the base of the burner and remove the *collar* from the barrel. Observe the small hole in the *delivery tube.* Attach the delivery tube to a gas-jet, turn on the gas, and light it. Describe the flame produced.

(*b*) Turn off the gas and replace the barrel and collar. Turn the collar so that the holes are closed. Light the gas. Describe the flame produced. Turn the collar so that the holes are open. What effect does this extra supply of air have on the size and color of the flame?

(*c*) Which is the hotter flame, the yellow or the blue? Obtain two beakers or tin cups of the same size. Pour just two inches of water in each beaker. Take the temperature of the water. Heat the water with the yellow flame for three minutes and record the temperature. Without changing the amount of gas, turn the collar so that the holes are open. Heat the other beaker of water for three minutes, recording the temperature before and after heating. What do you conclude?

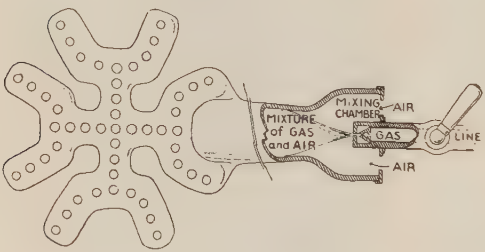


Fig. 216. Burner of a Gas Stove

The gas enters through the gas line and is mixed with the proper amount of air in the mixing chamber.

(*d*) Where is the hottest part of the blue flame? Hold a wire gauze horizontally at the highest point of the flame, then lower it until it is just above the inner blue cone, and finally hold it just above the barrel of the burner. In which part of the flame would you place a material to heat it in the least time to the highest temperature?

(*e*) Why is the blue flame hotter than the yellow flame? Hold a white dish in the yellow flame. Note that a black substance, *carbon*, collects on the dish. Repeat, holding a clean white dish in the blue flame. Is carbon given off by the blue flame? In which flame is the greater amount of burning taking place? Why? Recalling that the blue flame is smaller than the yellow flame when the supply of gas is the same, you can now give two reasons why the blue flame is hotter than the yellow. What are they?

Exercise 4. Write a report on Experiment 51, including answers to all questions.

The kitchen gas-stove burner (Figure 216) is similar in construction and operation to the Bunsen burner. Examine your gas burner at home and locate the *gas line*, or delivery tube, *air regulator*, and *mixing chamber*. Turn on the gas and light it. Are the small flames blue or yellow? If the tips of the flame are slightly yellow, the flames smoke. In adjusting the air supply, the holes are usually opened until the flame "strikes back," or explodes, when it is lighted. The holes are then closed slightly until no explosion takes place when the gas is lighted. This produces a mixture which secures the greatest quantity of heat from the smallest amount of gas.

Exercise 5. What is the difference in the operation and construction of a Bunsen burner and the kitchen gas stove?

PROBLEM 2: WHAT DOES A FIRE TAKE OUT OF THE AIR? ed

A fire uses but part of the air. Until 1777 it was thought that all of the air was necessary for burning. Previous to that time a gas had been discovered in which materials burned very brightly, but the experimenter did not know that this same gas was present in air and caused burning. You can readily prepare this gas in the laboratory.

Experiment 52: How can the gas which causes burning be prepared?

(*a*) Place enough red rust of mercury in a test tube to make a layer about one-eighth inch deep in the bottom of the tube. Heat the bottom of the tube, holding it in an inclined position (Figure 217) and rotating it slowly to heat it evenly on all sides. From time to time thrust a glowing splinter of wood into the tube. What happens? How do you account for this?

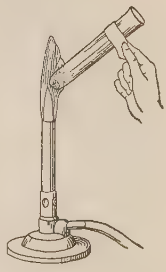


Fig. 217. Apparatus for Experiment 52

(*b*) Continue heating the tube until the red powder has completely disappeared. Remove the tube from the flame, and, holding the mouth downward, tap it against a piece of paper on the table. What comes out?

Lavoisier, one of the first great chemists, proved that this gas was the true cause of burning. By a series of experiments he showed that metals take this gas out of the air when they rust and that fuels will not burn in air from which this gas is removed. But if a rust, such as red rust of mercury, is heated and the gas passed back into this air, materials will again burn in it. In this way he demonstrated that the burning of fuels and the rusting of metals are caused by the same kind of gas. He called this gas oxygen.

How much of the air is oxygen? This question may be answered by experiment. Iron rusts when it is placed in air. When it rusts it takes up oxygen. You may take advantage of this characteristic of iron to find what part of the air is oxygen.

Experiment 53: What is the percentage of oxygen in the air?

(*a*) Fill a test tube with water and then pour out the water. This leaves the inside wall of the test tube moist. Sprinkle a pinch of iron filings or iron powder into the tube so that the filings are scattered over the inside wall. Invert the tube into a glass of water, and allow it to stand until the next day (Figure 218). What happens? How do you account for this? (See Experiment 22, page 122.)

Fig. 218. Apparatus for Experiment 53

(*b*) Hold the tube so that the water levels inside the tube and in the glass are the same. Place your finger or thumb over the mouth of the test tube, remove the tube from the glass, and turn it mouth upward. The water flows to the bottom. Remove your finger and lower a lighted match into the tube. What happens? Why? Does this prove the conclusion you reached in part (*a*)? Why?

(*c*) Measure the entire length of the tube, and then divide the length of the water column in the tube by the length of the tube. The result you obtain will be the percentage of oxygen present in the air. Why?

Careful experiments have shown that approximately 21 per cent of the air is oxygen. Compare the results which you obtained with the actual percentage of oxygen in air. How do you account for the difference? (See Table VI, page 150.)

Exercise 6. Why must fire have a constant supply of fresh air?

Exercise 7. Why do materials burn more brightly in pure oxygen than in ordinary air?

PROBLEM 3: WHAT IS FLAME?

2d

A burning piece of wood is hot. Before it is lighted, it is at the same temperature as the air around it. What is the source of the heat? In order to answer this question you must first consider some of the methods of producing heat. If you rub a coin on your sleeve a few minutes, it gets hot. The longer you rub, the hotter it gets. Like the wood before burning, the coin is cold before it is rubbed. In the rubbing of the coin, the energy of your muscles is transferred to the coin in the form of heat. Heat is simply another form of energy. Electricity is also a form of energy. When electricity is passed through the wires of an electric toaster, the electrical energy is changed into heat energy. One form of energy can thus be changed into another form of energy.

Exercise 8. Make a list of as many energy changes as you can. For example, electrical energy changes to light and heat energy in the electric lamp.

If you pour a few drops of glycerine on a small pile of powdered potassium permanganate, the mixture will burst into flame and produce both heat and light. The potassium permanganate and glycerine possess energy which is changed into heat energy whenever they come in contact. The energy which they possess is called *chemical energy.* All materials contain chemical energy. Under certain conditions this energy can be changed into heat energy. This is what takes place when a material burns. The chemical energy of the materials entering into the burning is changed into heat energy.

When things burn they also produce another kind of energy which we call light, and we say that the materials burn with a *flame*. Perhaps the simplest way to understand how the flame is produced is to study a burning candle.

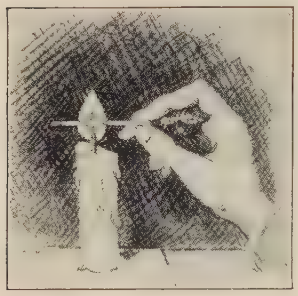


Fig. 219. Apparatus for Experiment 54

Experiment 54: Where does the burning take place in a candle flame?

Hold a match stick horizontally across the flame of a candle (Figure 219) just above the wick, until it starts to burn. Remove it quickly from the flame and extinguish it. Examine the stick. Does the burning take place inside of the flame or on the outside of the flame?

When a candle burns, it becomes shorter and shorter. The wax of which the candle is composed melts. The liquid which is formed may be seen in the cup-shaped cavity at the top of the candle around the base of the wick.

Experiment 55: How does the wax get to the part of the flame where the burning takes place?

(*a*) Light a candle, and when it is burning well, rapidly lower a piece of white paper, held in a horizontal position, downward until it just touches the wick, and then remove it quickly. Examine the piece of paper at the point where it touches the wick. What do you see? Account for the result.

(*b*) Obtain a glass tube about six or seven inches long and about three-eighths inch in diameter, drawn to a small opening at one end. The opening should have a diameter about one-half as great as the diameter of the tube. Warm the tube, and then hold it in the candle flame, as shown in Figure 220. Light the gas which comes out of the end of the tube. This gas is unburned wax gas. It is formed at the wick because of the heat of the flame which turns the liquid to a gas. When it reaches the outer part of the flame, it combines with oxygen and burns.

Exercise 9. On the basis of Experiments 54 and 55 and what you know about the nature of burning, write a scientific explanation in answer to the following question: "How does a candle burn?"

You know now how a candle burns, but you do not know why it burns with a visible flame.

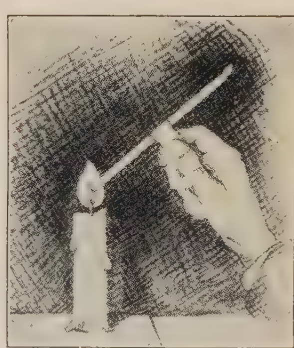


Fig. 220. Apparatus for Experiment 55

Experiment 56: Why does a candle burn with a visible flame?

(*a*) Hold a white porcelain dish in a candle flame for a minute. Remove the dish and examine the part which was in the flame. What do you observe? This material is carbon. How would you describe carbon?

(*b*) Light a Bunsen burner and close the holes by turning the collar at the bottom. Repeat (*a*). Do you get the same result?

(*c*) Light a Bunsen burner and open the holes. How does the flame compare with the flame obtained when the holes are closed? Repeat (*a*). Do you get the same result? Obtain a match which is thoroughly charred, and powder it. Introduce some of this black powder into the holes of the Bunsen burner. What effect does this have on the color of the flame? Note that when the particles are heated, they glow and color the flame. Scrape some of the carbon off the white dish and introduce it into the holes of a Bunsen burner. Do you get the same results as with the charred match?

Exercise 10. Explain how the last experiment proves that the color of the flame is due to glowing carbon particles.

All materials which burn with a flame change to a gas before they combine with oxygen. When the oxygen combines with the gas, great heat is produced. This heat raises the temperature of any solid particles which may be in the gas until they glow, thus giving a color to the flame. In case there are no solid particles in the flame, the flame has no color; it is a *non-luminous* flame. All our common fuels burn with a visible flame caused by the glowing carbon particles.

PROBLEM 4: WHAT BECOMES OF MATERIALS WHEN THEY BURN?

You know that fuels decrease in size when they burn (Figures 221 and 222). A candle gets shorter and shorter until finally only a very small part of it remains. Experiments have shown you that part of the candle goes into the air in the form of tiny black particles of carbon. This, however, does not account for the entire candle.

Courtesy Grinnell Co.

Fig. 221. A Famous Hotel Before Destruction by Fire

Most candles are made of a white solid called *paraffin*. It is composed of two substances: one of these is carbon, and the other is a colorless gas called *hydrogen*. It is hard to realize that a white solid could be made of a black solid and a colorless gas, yet this is true. You have seen in an earlier experiment that red rust of mercury consists of oxygen, a colorless gas, and mercury, a heavy silvery liquid. Both paraffin and red rust of mercury are *compounds;* that is, they are composed of more than one simple material. Oxygen, hydrogen, carbon, and mercury cannot be divided into simpler materials. They are therefore called elements. (See page 90.)

Experiment 57: How does mixing two materials together differ from combining two materials?

(*a*) Mix together equal parts by volume of sulphur and iron powder. Use enough of each so that you will have about one-half test tube of the mixture.

(*b*) Examine the mixture of sulphur and iron. Can you distinguish one from the other? Pour about one-fourth test tube of the mixture into water and shake thoroughly. Allow the mixture to stand for a few minutes. Are the materials now separated? Why?

(*c*) Place about one-half inch of the mixture of iron and sulphur which you made in (*a*) in a test tube. Heat the test tube in a flame until a red glow spreads throughout the mixture, and then remove the tube from the flame. Allow the contents of the test

Courtesy Grinnell Co.

Fig. 222. What Was Left of the Hotel After Burning

What has become of the solid materials of which the hotel was built?

tube to cool, and then break the test tube so as to secure the material. Crush the material. Examine it carefully. Can you distinguish between the iron and the sulphur? Pour the material in a test tube of water, shake it, and allow it to stand a few minutes. Compare your results with those obtained in (*b*).

You see from this experiment that when two materials are simply mixed together they do not change chemically. When two materials combine, as the iron and sulphur do when heated, a new material is formed which does not possess the same properties as the original materials.

Now that you know paraffin is a compound of carbon and hydrogen, you can determine by experiment what becomes of it when it burns.

Experiment 58: What becomes of a candle when it burns?

(*a*) Light a small candle and place a clean dry beaker mouth downward over the flame for a few seconds. Notice the film which covers the inside wall. This film is water. Another name for water is *hydrogen oxide*. It is formed by the combination of hydrogen and oxygen.

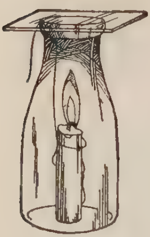


Fig. 223 Apparatus for Experiment 58

(*b*) Light a candle and lower it into a clean bottle or jar. Cover the jar (Figure 223). When the flame "goes out," remove the candle and pour enough limewater into the jar to make a layer about one-half inch deep. Cover the jar quickly with a glass plate and shake the contents. Observe that the limewater turns milky. Chemists have found that limewater turns milky only when a gas called carbon dioxide is present. The carbon dioxide is produced by the combination of carbon and oxygen.

The preceding experiment shows you that carbon dioxide and water are formed when a candle burns. Both of these materials are compounds, and when in the form of gases are colorless. To form them the oxygen must have combined with the elements in the paraffin. You can say, therefore, that when a material burns it combines with oxygen.

Our common fuels, such as wood, coal, gas, and petroleum, contain carbon and hydrogen; like the candle they also combine with oxygen and form carbon dioxide and water. If the temperature of the flame is hot enough to keep them at their burning temperature and there is plenty of oxygen, these fuels will disappear in the same manner as the candle. Of course, in wood and coal there are minerals which will not burn; these are left as *ashes*. (See page 88.) When large amounts of fuel are thrown on a fire, the fire generally smokes, because there is not sufficient heat to raise the fuel to the burning temperature nor enough oxygen to burn it.

Exercise 11. Why do materials disappear when they burn?

Exercise 12. State two reasons why a lamp smokes if the wick is turned too high.

PROBLEM 5: WHAT ARE OUR COMMON FUELS?

Our modern life is dependent to a great extent upon fuels. Without fuels, fire could not serve its purposes and life would be very primitive indeed. The wonderful progress which man has made in recent centuries depends to a great extent upon the principal uses to which fuel is put, namely, light, heat, and power.

The enormous quantity of the most important fuels used in the United States is almost unbelievable. Table VII shows the annual amounts used during recent years.

TABLE VII: FUELS USED IN THE UNITED STATES

Hard coal	48,824,127 tons (1922)
Soft coal	422,268,900 tons (1922)
Wood	100,000,000 cords (1923)
Coke	55,487,000 tons (1923)
Petroleum consumed*	711,000,000 barrels (1922)
Natural gas	762,546,000,000 cu. ft. (1922)

*Not all used for fuel.

Wood is still an important fuel. Wood was in many places probably the first fuel. It was easily obtained and the supply was plentiful. The early pioneers in the United States were wholly dependent upon it. But as the population increased, more land was needed for farming and more timber for building. The land was cleared to make way for fields of grain and other food-producing plants. Timber was necessary to supply man's wants, that is, to build him a shelter, to keep him warm, to make furniture, and to furnish him with the tools and conveniences which made possible a more comfortable and more efficient life. So the forests gradually disappeared.

As wood became less plentiful, it became more expensive. It had to be shipped greater distances, and the cost of shipping was added to the cost of cutting. These additional costs made it more expensive than coal, especially in cities

where enormous amounts of fuel were used. The coal could not only be produced and shipped more cheaply, but it required less space for storage. You see the truth of this statement when you realize that a wagon-load of coal gives about three to four times as much heat as a wagon-load of wood, or that a pound of coal gives as much heat as two pounds of wood. The clearing of the land and the many uses of wood for other purposes caused a great decrease in the amount used as a fuel. Even so, approximately one hundred million cords of fuel wood are used every year in the United States. At a cost of four dollars and seventy-five cents a cord this has a value of $475,000,000.

Fig. 224. Soft Coal

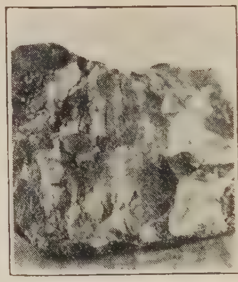


Fig. 225. Hard Coal

The soft coal breaks along definite lines, producing jagged surfaces. Hard coal will not crumble and shows curved surfaces.

Coal is our most important fuel. The two principal kinds of coal are hard, or *anthracite*, and soft, or *bituminous* (Figures 224 and 225). In the mining of coal, shafts are sunk into the ground and tunnels, or galleries, run off from them at different levels. The coal occurs in horizontal layers (Figure 226). The composition of coal is the real basis upon which coals are classified by scientists, because it is the composition which will determine the properties and uses of the coal. Table VIII shows the composition of these two kinds of coals. Note the large amounts of fixed carbon in the anthracite and the high percentage of *volatile* matter in the bituminous. "Volatile" refers to the part which escapes as a gas when the coal is heated; "fixed carbon" refers to the carbon that is left after the gases are driven off.

Keystone View Co.

Fig. 226. Mining Soft Coal

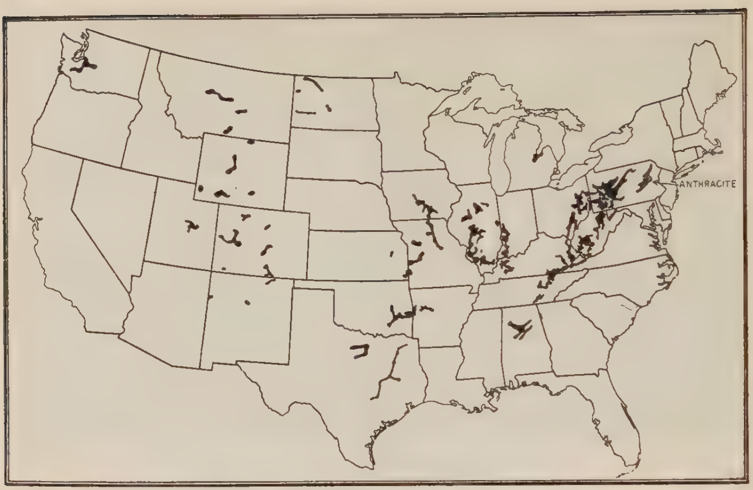
These men are using an electrically operated device for cutting channels into the coal so that it may be more easily loosened and broken up.

Anthracite coal is frequently used in heating houses, because it is a clean fuel. It contains so little volatile matter that it burns with practically no smoke. Since it burns slowly, stoves or furnaces need to be filled but once or twice a day. Bituminous coal is by far the more important kind. Manufacturing plants and locomotives use enormous quantities of it for generating steam power, and many buildings are heated with it. Since the coal contains so much volatile matter,

TABLE VIII: COMPOSITION OF SAMPLES OF COAL

	ANTHRACITE	BITUMINOUS
Fixed carbon	95.4%	54.2%
Volatile matter	1.3%	40.8%
Moisture	3.3%	5. %

much smoke results from its burning, unless the amount of fuel, the supply of air, and the temperature of the furnace are carefully controlled.



Courtesy U. S. Geological Survey

Fig. 227. Principal Coal Fields of the United States

Note the small anthracite field. There are a few minor deposits of hard coal in other sections of the United States.

Exercise 13. The principal coal fields of the United States are shown in the map (Figure 227). From this map make a list showing the different states which produce hard and soft coal.

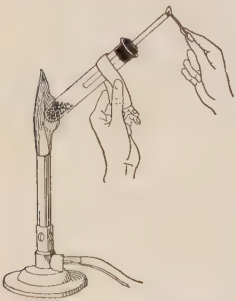


Fig. 228. Apparatus for Experiment 59

Gas is manufactured from coal. Soft coal is also employed in the making of *coal gas,* which is used in many cities for f iel.

Experiment 59: How can you make gas from soft coal?

Set up an apparatus as in Figure 228. Remove the stopper from the test tube and place in the tube a number of small pieces of soft coal. Replace the stopper and heat the tube by moving a flame back and forth under it. Observe what happens. When smoke comes from the small opening at the end of the delivery tube, bring a flame to this opening. What happens? Heat the test tube until no more gas is

obtained. Allow the tube to cool. Break the tube and examine the contents. This is *coke*. Also note the brown liquid on the sides of the tube. This liquid is *coal tar*.

In the commercial manufacture of coal gas, the coal is heated in iron retorts (Figure 229). The gas which is driven off from the coal contains coal gas, coal-tar gas, and ammonia

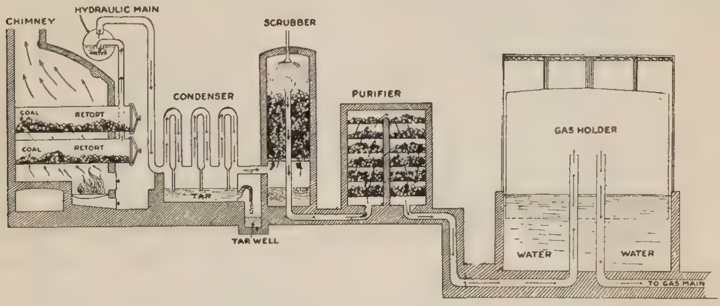


Fig. 229. A Coal-Gas Plant

There are three steps in the process of making gas from coal: first, the gas is liberated from the coal in the retorts; second, the gas is purified; third, the gas is collected for distribution.

gas. These gases pass upward to the *hydraulic main*, which is a long horizontal pipe containing water. Part of the *ammonia* gas is absorbed here. In the *condenser* the coal tar is condensed and collects in the tar well. In the *scrubber* the rest of the ammonia gas is absorbed by the spray of water. The *purifier* contains various chemicals which combine with any sulphur compounds contained in the gas. The gas collects in the *gas holder*, from which it is distributed to the consumer.

Exercise 14. How does the gas you prepared in Experiment 59 differ from commercial coal gas?

Gas is sold at a certain rate per 100 cu. ft. The cost varies in different places and at different times. Large manufacturing plants which consume enormous amounts of gas obtain their supply at a lower rate than do private consumers of small quantities. The gas meter measures the volume of gas burned, and our gas bills vary with the quantity used. The meter

indicates exactly the number of cubic feet of gas which pass through it. The operation of the meter is rather complex and difficult to understand, but anyone can read his gas meter by knowing how the small dials and hands indicate the gas used.

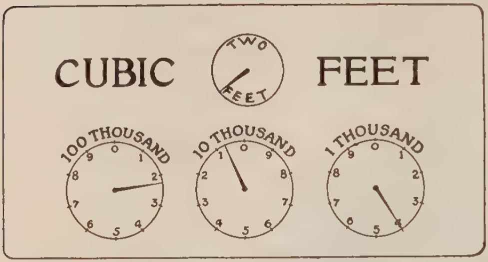


Fig. 230. Reading of Gas Meter on First Day of Month is 20,400 cubic feet

Exercise 15. Suppose Figure 230 shows the reading of the meter on the first day of a month, and Figure 231 shows the reading on the last day of the month. Suppose also that the cost of gas is $1.10 per 1000 cu. ft. What will be the gas bill at the end of the month?

The use of oil for fuel is increasing. In recent years the use of oil, or petroleum, for fuel has increased tremendously. A large number of ships are now burning oil instead of coal, because it has been shown that for their use, oil is cheaper, cleaner, and produces less smoke than coal. The use of oil in home furnaces is also rapidly gaining a hold. Oil is slightly more expensive than coal for this purpose, but oil furnaces are much more easily regulated than coal furnaces and require much less attention.

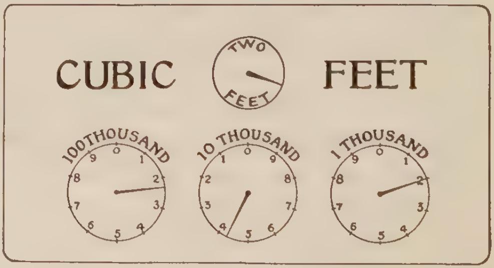
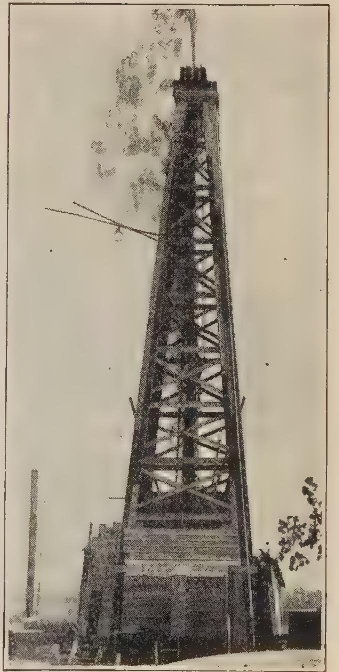


Fig. 231. Reading of Gas Meter on Last Day of Month

The petroleum, called *crude oil*, is obtained from the ground by drilling holes through the soil and rock into the oil-bearing

layers (Figure 232). The rocks in which the oil is found are called *pay-sands*. The crude petroleum which comes from the wells is a black oily liquid. It contains gasoline, fuel oil, kerosene, lubricating oil, paraffin, and several other ingredients.

Each of the liquids present in the crude oil has its own boiling point, and therefore each of the ingredients can be separated from the others. The oil is put in a large retort and heated for several hours to the boiling point of the most volatile liquid. The gas which comes off is led through a pipe cooled by water flowing over the pipe. The gas condenses, and the liquid flows from the pipe to be collected in tanks. Then the temperature is raised to the boiling point of the next most volatile liquid, until it has changed to a gas, and so on until the gases cease to be formed. This process is called *fractional distillation*. The remaining material, a black tarry liquid, is cooled suddenly, and flakes of paraffin appear in it. This mixture is then poured through a cloth. This holds the paraffin, which is later purified.



Underwood and Underwood

Fig. 232. An Oil Gusher

The oil is spouting into the air through the center of the derrick.

Exercise 16. What is the difference between the distillation of water and the distillation of petroleum? (See page 138.)

Natural gas is used in many regions. Natural gas is obtained in much the same way as oil. When the drill-pipe reaches the gas layer, the gas, being greatly compressed by

the layer of rock above, rushes out of the pipe with great force until the well is exhausted. Pipes carry the gas to storage tanks near the well or in neighboring cities.

Conservation of fuels is necessary. The amount of fuel used in the world is so great that we may soon be faced with a fuel shortage. For this reason we must *conserve* our fuels. There are several ways in which this may be done. One way is to eliminate waste in handling and storing. Enor-

Keystone View Co.

Fig. 233. A Burning Oil Well

Millions of dollars' worth of oil are destroyed every year by fire.

mous quantities of coal and wood are left on the ground and are never recovered. It is a common practice in boring for oil to "blow off" the gas which accompanies the oil in order to get the more valuable product. Great quantities of oil are lost because of fire and careless handling at the wells (Figure 233). Proper care of fuels will prevent great waste.

A common method of wasting fuel is burning without the correct amount of air. Nearly one-third of the heat value of the coal used in our country passes up the chimney. This

loss can be eliminated by the proper control of the drafts and by proper feeding of the fuel. New inventions on stoves, furnaces, and heating devices of all kinds are needed as aids in the saving of fuel. Thus, by means of making our heating devices more efficient we have another way by which we may conserve fuel.

The development of water power is one hope for the solution of the fuel problem. Very little of the water power available in this country is utilized. Water power may be used to generate electricity, which can be transported long distances to run our machinery and furnish us with light and heat. If all this available power were used, it would result in a great saving of coal.

What the future has in store for us in the way of new fuels cannot be predicted. Fuels having as their sources some new materials may be developed. There will always be a demand for fuel, and if new materials are found, they in turn will some day be exhausted, and new sources must again be found.

Exercise 17. Make a summary of the principal ways by which our present supply of fuels may be conserved.

Exercise 18. List the ways in which you can help save fuel.

PROBLEM 6: HOW CAN DESTRUCTIVE FIRES BE PREVENTED?

"Fire is a good servant but a bad master." When properly controlled, fire serves us in many important ways. Once beyond control, it is very dangerous and destructive. You have only to consider the great losses due to fire to appreciate the truth of this statement. In the United States alone the losses caused by fire amount to nearly one-half billion dollars every year. This loss would build 50,000 houses at 10,000 dollars each. Add to these material losses the suffering of the injured and homeless and the lives lost, and you are impressed with the great necessity for better methods of fire

Keystone View Co.

Fig. 234. A Million Dollar Fire

Beautiful homes had occupied this area.

control (Figure 234). A great fire-extinguisher company states this loss in the following words:

> All of the buildings burned in the United States in a single year, if placed on one side of the street, would make a dreadful avenue of desolation reaching from Chicago to New York City, the milestones of which would be the charred bodies of human victims of fire.

When one realizes that the majority of destructive fires are preventable, this tremendous loss of property and human lives is even more terrible. The development of new fireproof building materials and increased care in the construction of buildings have done much towards preventing the rapid spread of fire, but the real prevention of fire is in the hands of the individual. If every person would make a continuous effort to take the proper precautions when using fire materials, this great loss would be nearly eliminated.

The causes of these destructive fires may be classified under three heads. Table IX shows these three classes, and under each suggests several causes which belong to that class.

Table IX: Causes of Preventable Fires

1. Careless handling of fire and fire materials.

Throwing lighted matches on combustible materials.
Allowing trash piles to accumulate.
Dumping ashes that contain live coals.
Overheating stoves.
Burning out of chimneys containing much soot.
Rolling up oily rags (spontaneous combustion).
Storing coal where little air circulates (spontaneous combustion).
Storing uncured hay (spontaneous combustion).
Lighting matches in a garage.
Bringing lighted matches near gasoline tanks.
Using gasoline or chloroform to clean clothes.
Filling kerosene or gasoline lamps while using a lamp to furnish light.
Placing a lamp or a lantern where it can be easily upset.
Starting fires in stoves with kerosene or gasoline.

2. Electricity.

Driving nails into electric wires and causing "short-circuits."
Using wrong kind of fuse for the kind of circuit.
Attaching too many electrical devices at the same time.
Using wires too small for a heavy current.
Rubbing the insulation off wires.
Wiring buildings without proper insulation.

3. Faulty construction of heating devices and buildings.

Defective oil stoves.
Leaking gasoline tanks.
Stoves placed over wood or carpets.
Fireplaces without screens.
Poorly constructed flues and chimneys.
Running pipes near combustible materials.
Improper closing of openings between rooms and corridors.
Using combustible materials for buildings.

Exercise 19. Add 10 other causes of preventable fires not included in this list. After each cause, list some method or methods of preventing fires due to that cause.

PROBLEM 7: HOW ARE FIRES "PUT OUT"?

To prevent a fire is less difficult than to put it out. However, the fire can be extinguished easily while it is small. You have only to keep in mind the requirements of a fire. Every method of extinguishing fire does one or both of these things: (1) it cuts off the supply of air, or (2) it cools the fuel below its burning temperature.

Courtesy Pyrene Co.

Fig. 235. A Commercial Carbon-Dioxide Fire Extinguisher

When water is thrown on a fire, it cuts off the supply of air by covering the fuel with water and with the steam which is formed. The water also cools the fuel below the burning temperature. For extinguishing small fires but little water is necessary, since the amount of heat given off by the fire is not great. In large fires there is so much heat that it is sometimes difficult to cool the fire. Moreover, the water cannot easily reach all parts of the burning materials even when thrown by the fire engines. Water is the most important fire extinguisher because it is available in large quantities.

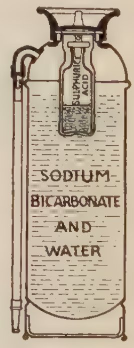


Fig. 236. Sectional View of Carbon-Dioxide Fire Extinguisher

Carbon-dioxide extinguishers may be used for some fires. You recall that carbon dioxide is a product of burning and cannot therefore itself burn. You might expect it to be a good fire extinguisher, if, in some way a fire could be covered with the gas, which would cut off the supply of fresh air. Figures 235 and 236 show a carbon-dioxide extinguisher. Note the small bottle of sulphuric acid which is attached at the top, the solution of baking-soda in the tank, and the position of the tube.

Experiment 60: How is a carbon-dioxide fire extinguisher made and used?

(*a*) Dissolve a few spoonfuls of baking-soda (sodium bicarbonate) in about a half-pint of water. Place the solution in a glass or beaker and then add to it a few drops of concentrated sulphuric acid. The gas given off is carbon dioxide.

(*b*) Set up a small demonstration fire extinguisher like that shown in Figure 237. The solution of soda is made in the way described above. This should fill the bottle about two-thirds full. Place sulphuric acid in the small vial to a depth of one inch. Insert the stopper tightly by a twisting motion. Now invert the bottle quickly, emptying the acid into the soda solution, direct the stream of liquid into a pail on the floor, and bring it to an upright position. **Be careful that the stream of liquid does not come in contact with your clothing.** Here you have a real carbon-dioxide fire extinguisher.

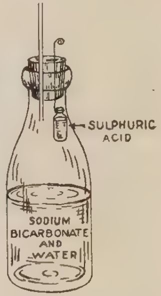


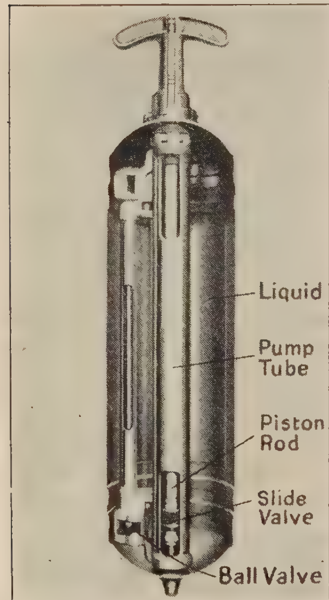
Fig. 237. Demonstration Fire Extinguisher

(*c*) Refill the extinguisher and test it on a small paper fire out-of-doors.

In some commercial extinguishers the bottle is placed in such a position that, when the tank is inverted, the acid will flow out. In others the cover is fitted with a screw-plunger which, when screwed down, breaks the bottle and allows the acid to mix with the soda solution. The carbon dioxide collects above the water in the tank. Soon the pressure of the gas is great enough to force the water out of the tube. If the gas is made very rapidly, the water spurts from the tube and can be thrown on a fire at some distance. The water lowers the temperature of the fire and cuts off the supply of oxygen. The carbon dioxide also helps to cut off the oxygen supply, because it is about one and one-half times as heavy as air. In a closed room where there are no currents of air, the carbon dioxide may be of considerable value. In open places the carbon dioxide might be carried away by wind, but the water would put out a small fire.

Exercise 20. Is the carbon dioxide or the water more important in the commercial fire extinguisher? Why do you think so?

Carbon-tetrachloride extinguishers are very practical (Figure 238). Many of these small "handy" extinguishers are used in automobiles, in houses, and in other buildings. The carbon tetrachloride changes to a vapor at very low temperature. The vapor is about five times as heavy as air, and will neither burn nor support burning. Because of these properties it is an excellent fire extinguisher. A small force pump operated by a handle at the top of the extinguisher, throws the liquid a considerable distance. For small fires the extinguisher is very serviceable (Figures 239 and 240).



Courtesy Pyrene Co.

Fig. 238. Construction of Carbon-Tetrachloride Fire Extinguisher

When the piston-rod is pulled upwards, a partial vacuum is produced in the pump-tube. The liquid then enters through the ball valve into the pump-tube. On the down stroke the liquid flows through the slide-valve into the hollow piston-rod and is forced out the nozzle.

Experiment 61: Why is carbon tetrachloride instead of water used to extinguish gasoline fires?

(*a*) Pour a small quantity of gasoline in an iron or porcelain dish and light it. Slowly pour some water on the burning gasoline. Does the water extinguish the flame? Explain the result.

(*b*) Repeat (*a*), pouring carbon tetrachloride instead of water on the burning gasoline. Is the fire extinguished? Why?

There are still other ways of extinguishing fires. For gasoline, kerosene, or oil fires, water is not a good extinguisher. Carbon tetrachloride is too expensive and is not always at

hand. Sand or dirt can be used. These materials cover the fire and exclude the necessary air. When clothes catch on fire, a blanket should be wrapped around the person. In place of the blanket, a coat, rug, or any similar material can be used. Woolen materials are best for this purpose. To

Courtesy U. S. Bureau of Standards

Fig. 239. Wrong Way to Put Out a Fire

Fig. 240. Right Way to Put Out a Fire

The flames are rising from the fire near the floor. The liquid should always be directed to the point where the burning is taking place, and not on the flames above.

rush out of doors or to try to run away from such fire, only serves to furnish a better supply of fresh air, and thus the fire burns better.

Exercise 21. Make a sentence outline of a story on "How fires are extinguished."

Review Exercise on Unit VIII. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit VIII and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT VIII

1. Why are there holes in the base of a burner of a lamp?

2. What should be done to correct a smoking lamp?

3. Why does carbon dioxide sometimes remain in wells or cisterns from which most gases would escape?

4. Iron rusts when exposed to the air. How may such rusting be prevented?

5. Why do workmen lower a lighted lantern into an old well before they descend into it?

6. Why is it necessary to strike a match?

7. When a hard-coal burner goes out, why is it hard to start again?

8. If atmosphere were composed wholly of oxygen, what would happen?

9. How can the smoke of a city be lessened?

10. Why does not the carbon dioxide produced by a flame extinguish it?

11. Why does smoke go up the chimney?

12. Why do factories have high chimneys?

13. Why do you blow on a fire to make it burn, and blow on a match to put it out?

14. What effect does the presence of nitrogen in the air have upon burning?

15. Is the expression "cold air is heavier than warm air" correct? Explain.

16. How did the study of rusting of metals help you to understand the nature of burning?

17. Explain why a pile of burning leaves gives off much smoke when a new supply of leaves is thrown on the fire.

18. Explain why a teakettle full of cold water will often become coated with a film of water on the bottom of the kettle when placed over a lighted gas burner.

19. Why do flames flicker above a coal fire?

20. Make a survey of the destructive fires in your community during the past year. Determine how these fires might have been prevented.

21. Collect newspaper accounts of destructive fires. Learn from them the causes of the fires and the amount of the damage.

UNIT IX

PROVIDING HEAT AND FRESH AIR IN OUR BUILDINGS

Preliminary Exercises

1. How were buildings heated before the invention of stoves?
2. What is the common method of heating the house in the country? In the city?
3. Describe the heating system in your house.
4. How does the heat from a furnace in the basement get to you when you are in a room on the second floor?
5. Make a list of the kinds of stoves used for cooking.
6. In what ways is a furnace better than a stove for heating a building?
7. How does a heating system help ventilate a building?
8. Why are heating and ventilating often considered as one problem?

THE STORY OF UNIT IX

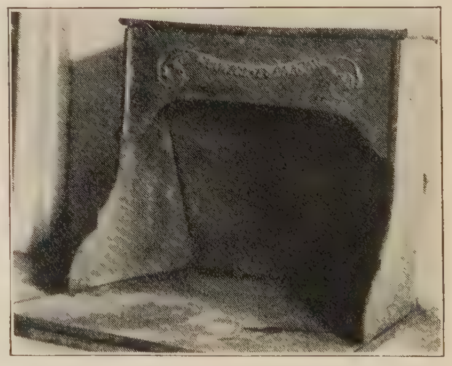
There are three important purposes for which heat from fires is used in the home. These are: (1) to keep the temperature of the air comfortable, (2) to provide fresh air, and (3) to cook our foods. In Unit VIII you learned how fuels burn and produce heat; in this unit you will see how man makes use of fire and fuels in heating and ventilating his buildings, and in cooking.

How would you like to have your house heated by an open fire in the corner of the room? A little over two thousand years ago this was the common method. Less than a thousand years ago the only improvement which had been made was the addition of a hole in the roof so that the smoke might escape. Later, fireplaces were constructed at one side of the room and a chimney was added. This type of fireplace is

even yet in common use in many parts of Europe. The next improvement was to locate the fireplace in the wall and build up the chimney from the outside (Figure 241). Old colonial houses in the United States had fireplaces constructed in this manner, and such fireplaces are becoming more and more common in modern houses.

Fig. 241. A Colonial Fireplace

In 1742 Benjamin Franklin made a great improvement on the fireplace. It was a simple thing, but it led to the construction of the modern stove. He built a device having three sides, made of sheets of metal (Figure 242). This he placed inside the fireplace. When the metal became hot, it gave off much more heat to the room than did the open fireplace. Franklin's idea led to the construction of the closed stove with a stove-pipe leading to the chimney. Still the stove was not satisfactory. Ashes were scattered on the floor, the stove took much space, and only the room in which the stove was placed could be sufficiently heated.

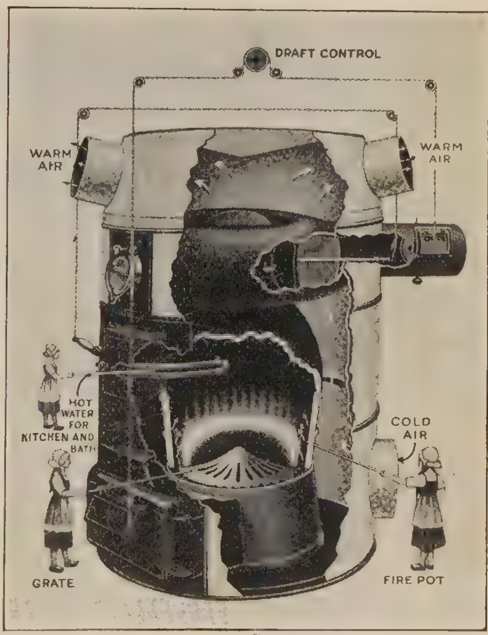


Underwood and Underwood

Fig. 242. Franklin's Stove

A furnace placed in the basement was the next improvement. This furnace consisted of a large stove surrounded

by an outer jacket containing air (Figure 243). As the air in this *hot-air chamber* was heated, a convection current was set up, and the warm air was thus forced through pipes to the rooms above. Somewhat later the space between the jacket and the firepot was filled with water, and pipes were provided to carry the heated water to the different rooms (Figure 244). However, in large buildings the transfer of heat by convection currents of air or water is not satisfactory. The steam furnace, in which water may be changed into steam and the steam forced through the pipes by pressure, is used in these buildings (Figure 251, page 269).

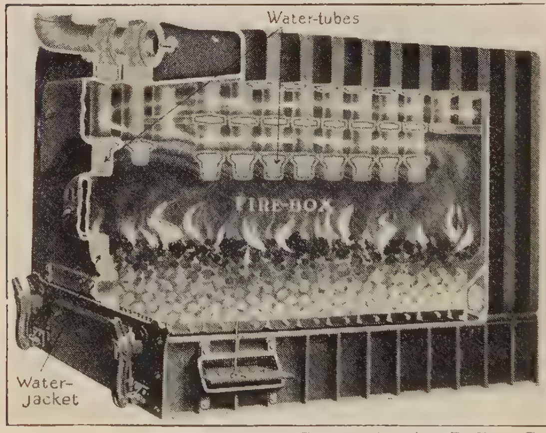


Courtesy Holland Furnace Co.

Fig. 243. A Hot-Air Furnace

In order to heat a building it is necessary for the heat to be transferred from the fire in the furnace, stove, or fireplace to the different parts of the building. This transfer of heat takes place in different ways. The heat from the fire warms the metal sides of the stove or furnace and is conducted through the metal, warming the air or water, which in turn carries the heat to different parts of the building. In open fires, such as the fireplace, most of the heat is transferred as radiant energy. (See pages 39, 176, and 179.) In the problems which follow, each of these methods of heat transfer will be studied in greater detail.

In addition to keeping the air in the house at the proper temperature, provision must be made to secure a frequent change of air by ventilation. Natural ventilation is, of course, supplied by opening windows and doors; artificial ventilation has been developed in connection with the different heating devices. There are three requirements for good heating and ventilation: (1) the correct temperature (68°-70°F.), (2) the proper humidity (see page 47), and (3) a satisfactory quantity of fresh air. Heating and ventilating are so closely related that they are really parts of the same problem. Any method of heating must be judged upon the basis of these three requirements of correct temperature, proper humidity, and sufficient supply of fresh air.



Courtesy American Radiator Co.

Fig. 244. A Hot-Water Heating Furnace

The hot water passes upward through the pipe shown in the upper left-hand corner of the picture. The return pipe, which cannot here be seen, enters at the bottom of the furnace.

PROBLEM 1: WHY DOES A STOVE HEAT A ROOM BETTER THAN A FIREPLACE?

How heat is transferred. You have already studied the construction of a stove (see page 231), and you know how the fire in it is regulated. The question which you will have to answer is "How is the heat of the fire transferred to the air, to the walls, and to the objects in the room?"

Experiment 62: How is the heat of the fire transferred to the stove walls?

(*a*) Light a candle. Hold your hand about six inches above it. Can you feel the heat? Hold a piece of burning punk or smoking paper above the candle flame. Note the direction of the particles of smoke which are carried along by the air currents.

(*b*) Place your hand at the side of the flame at a distance of two or three inches. The air between your hand and the candle moves toward the flame. How do you explain why your hand is warmed when the air between your hand and the candle moves toward the flame? (See pages 39 and 176.)

Inside the stove a convection current is set up because of the difference between the temperature of the air over the fire and that of the air outside of the stove. Why? (See pages 57 and 231.) The particles of gas which come from the burning fuel are hot. As they pass upward from the fire, they touch the sides and top of the stove and give up part of their heat to the metal. At the same time the fire is radiating energy to the sides of the stove and warming them.

The heat must then pass through the metal walls of the stove.

Experiment 63: How does heat travel through the metal walls of the stove?

Hold a long nail in the flame of a Bunsen burner or candle. Note that the end which you are holding becomes hotter and hotter, but never gets as hot as the end which is in the flame.

How does the heat travel to your hand? Do the particles of iron near the fire travel through the iron and give up their heat to you? It is evident that you have here a method of heat transfer which is different from convection. The iron, like all other materials, is made of small particles, called *molecules*. The molecules in the part of the nail held in the flame received heat from it. Each of these molecules then passed on a little heat to its neighbor. The neighbor passed on some to the next molecule, and so on. In time the end of the iron you hold in your hand receives this heat, and it gets hotter and hotter. This method of heat transfer from particle to

particle is called *conduction*, and it is the way that heat travels through the metal walls of the stove. (See page 176.)

How a room is warmed by a stove. After the walls of the stove are heated, they must pass on their heat to the room and the objects in the room. The particles of air in contact with the stove are heated by conduction. This sets up a convection current in the room, as shown in Figure 245, because of the differences in temperature of the air. These particles of heated air give up part of their heat to the walls and objects in the room when they come in contact with them. The walls and objects are also heated by radiation from all parts of the stove, as shown in Figure 245. The stove thus heats a room by all three methods of heat transfer.

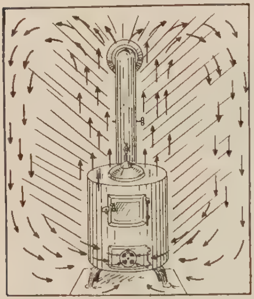
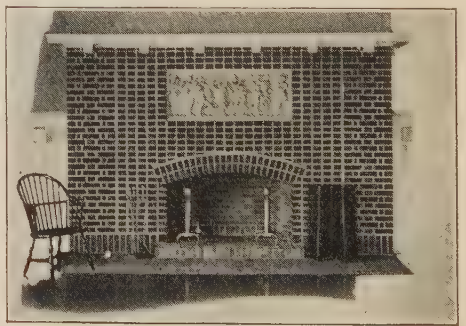


Fig. 245. Convection Currents and Radiation.

Arrows show convection currents and lines show radiation.

Exercise 1. Suppose there is a box of candy on the table in a room with twenty boys and girls. Suppose that the boys and girls represent molecules of air and the candy represents the source of heat. How could each boy and girl obtain candy in a way which illustrates the transfer of heat by convection? By conduction?



Courtesy American Face Brick Association

Fig. 246. A Modern Fireplace

The fireplace is less efficient than the stove. The fireplace (Figure 246) heats a room largely by radiation. The fire is built on a grate, and the hot gases immediately pass up through the chimney, giving but a

small part of their heat to the room. The walls of the chimney are heated by the hot gases, and this heat passes through the walls by conduction. The air in contact with the wall of the chimney is thus heated and sets up a small convection current. The radiant energy from the fire passes through the room to the walls, warming the air but little, and is changed to heat when it strikes the walls. The furniture and other objects in the room are warmed in the same manner. The walls and furniture heated by radiation give up part of their heat to the air and produce convection currents. The fireplace is not an efficient heating device, because most of the heat escapes through the chimney.

Exercise 2. Make a drawing of a room with a fireplace. Show by dotted lines the part of the room heated by radiation. Draw arrows to show the direction of the convection currents in the room.

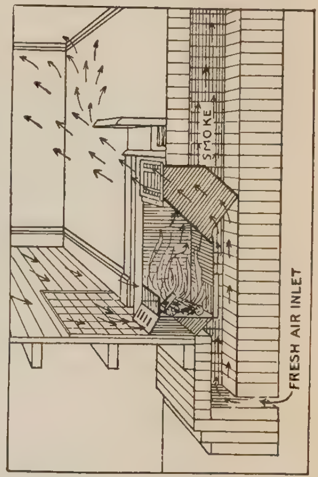


Fig. 247. A Ventilating Fireplace

The pipe which brings fresh air from the outside is not as wide as the fireplace; so the hot gases and smoke pass up the chimney on both sides of the pipe.

The most modern and efficient fireplace is the *ventilating fireplace* (Figure 247). Fresh air is brought into the room by a metal pipe which passes up behind the fireplace and over the top of the fire, opening into the room. The hot gases from the fire pass around the pipe as they escape into the chimney, and warm the fresh air as it enters the room. Why does the fresh air come in through the pipe? The ventilating fireplace heats the room in the same manner as the ordinary fireplace, and, in addition, uses the hot gases which pass up the chimney to heat the fresh air, thus starting a convection current in the room.

Exercise 3. Draw a room with a ventilating fireplace. By arrows show the direction of the convection currents in the room.

Exercise 4. Make a drawing of a room with a stove placed at one side of the room. Show by means of arrows the direction of the convection currents in the room. Show by dotted lines some of the paths of radiant energy.

Exercise 5. If the same amount of fuel is burned in a stove and a fireplace, which will give the more heat to the room? Explain.

Exercise 6. Why does the fireplace furnish better ventilation than a stove?

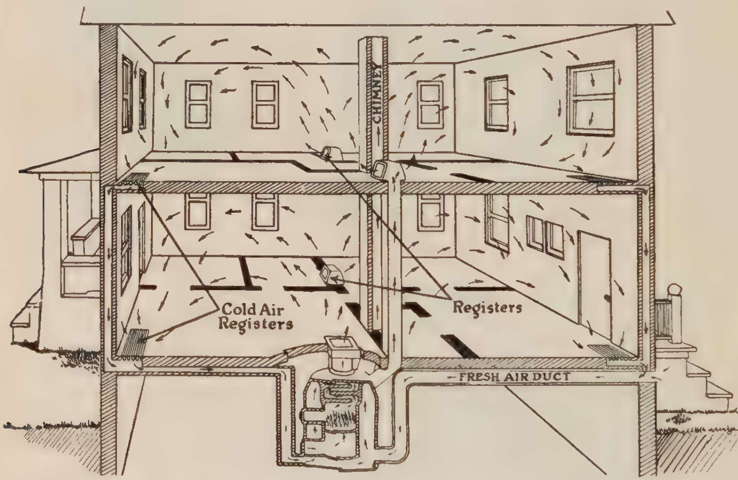


Fig. 248. A Hot-Air Heating Plant

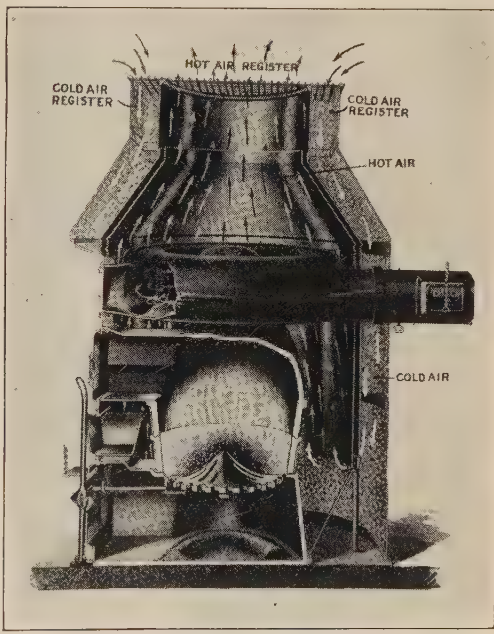
Examine also Figure 243, which shows the construction of the furnace.

PROBLEM 2: HOW DOES A HOT-AIR FURNACE HEAT AND VENTILATE A BUILDING?

If you examine a hot-air furnace, you see that it is simply a large stove surrounded by an air chamber (Figure 243). Leading away from this chamber are several pipes, or *ducts*. Trace each one of the ducts shown in Figure 248. Where do they go? In the rooms you find a grating, or *register*, over the

duct. The figure shows two registers in each room; one is called the hot-air register, and the other is called the cold-air register. The air rises through one duct and falls in the other because of the convection current which is produced. Explain how the convection current is produced. (See page 57.)

In recent years the *pipeless furnace* (Figure 249) has also come into common use. This furnace is generally placed in the middle of the basement. A hole is cut through the floor and fitted with a register directly over the hot-air chamber of the furnace. This register serves a double purpose, in that warm air rises from the center and cold air falls through the sides, as shown in Figure 249. Hot-air and cold-air registers are placed in the ceilings so that the heated and cooled air may pass to and from the other rooms.



Courtesy Holland Furnace Co.

Fig. 249. A Pipeless Hot-Air Furnace

This type of furnace is adapted especially to heating small houses. Its advantages are low cost of installation and minimum amount of fuel consumed.

Exercise 7. Make ~~a section~~ drawing of the hot-air furnace and pipes. Label ~~the parts,~~ and by arrows show the direction of the air through the ducts~~.~~ Explain how the house is both heated and ventilated by the hot-air system (Figure 248).

PROBLEM 3: HOW DOES A HOT-WATER HEATING PLANT OPERATE?

The hot-water heating plant (Figures 244 and 250) differs from the hot-air furnace in two ways: (1) the space between the jacket and the firebox is filled with water, and (2) the hot water is carried to the rooms through pipes called *risers*, where it circulates through a *radiator*, and is then returned by pipes called *returns* to the water jacket, or *heater*. The direction of the hot water through the pipes is shown in Figure 250.

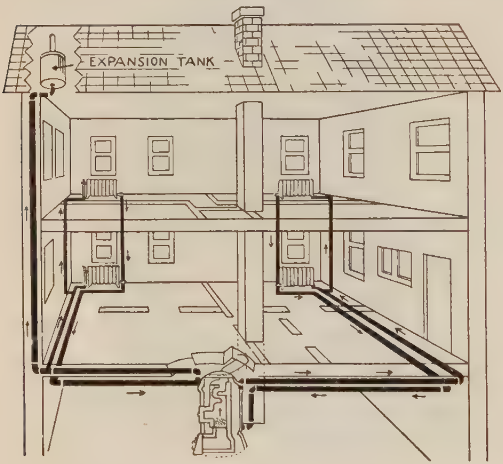


Fig. 250. A Hot-Water Heating Plant

The risers connect with the top of the heater and the returns connect at the bottom.

Exercise 8. Explain why the water circulates through the pipes. (See page 130.)

The hot-water system must be full when it is started, and this makes an outlet necessary to take care of the increased volume of water. Why does the volume of water increase? (See page 44.) An expansion tank is usually placed in the attic and is connected by a pipe to the heater. Leading from the top of the expansion tank to the roof is a small pipe through which the water may overflow.

The amount of heat carried to a room can be regulated by closing or opening a valve in the pipe which brings the water to the radiator. Refer to Figure 250, and explain why closing the valve on one radiator does not stop the flow of water in other radiators.

Exercise 9. Make a drawing of a room containing a radiator; show by arrows the direction of the convection currents in the room, and by dotted lines the part heated by radiation.

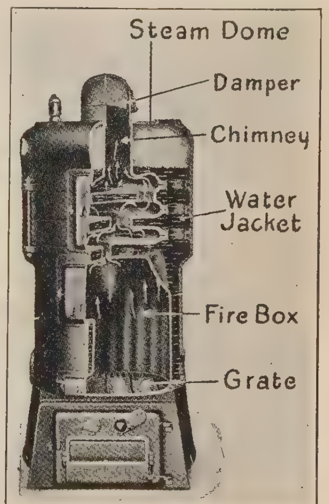
Exercise 10. Contrast the ventilation of a room by a hot-air furnace and by a hot-water furnace.

PROBLEM 4: HOW DOES A STEAM HEATING PLANT OPERATE?

In a steam heating plant water is changed into steam in a boiler placed over the firebox (Figure 251).

Experiment 64: How is water changed to steam?

Pour some water in a tall beaker and place it over a wire gauze. Put a thermometer into the beaker. Place a burner under the gauze and light the gas. In a short time small bubbles appear. These are bubbles of air. Take the temperature. Continue to heat the water, until very large bubbles are formed. These bubbles are steam. Soon the bubbles of steam reach the surface of the water and escape into the air. Take the temperature.



Courtesy Thatcher Manufacturing Co.

Fig. 251. A Steam Furnace

Steam collects in the dome, from which pipes lead to the different rooms.

Water always contains air dissolved in it. When water is heated, the air is driven off and escapes as tiny bubbles. As the water is heated more, it expands, and finally large bubbles of steam are formed. Since these bubbles are lighter than the water, they rise to the surface and escape. The temperature at which the water changes to steam is its *boiling point.* In an open vessel this is approximately 100° C.

Scientists explain the expansion of any liquid like water by assuming the liquid is made up of millions of tiny particles called molecules. It is believed that when the liquid is heated, these molecules move farther apart, and therefore the liquid takes up more space. Finally the distance between the molecules is so great that the liquid changes to a gas, causing bubbles of steam to rise from the liquid. Although molecules have never been seen, a great many facts, like expansion and the change of a liquid to a gas, can be explained satisfactorily by this assumption, or *theory*. It is altogether probable that this is a correct explanation.

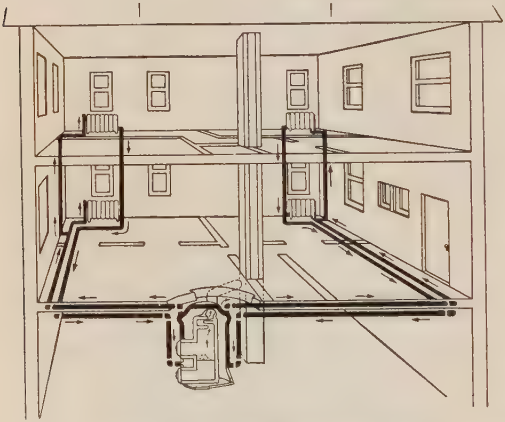


Fig. 252. A Steam Heating Plant
Examine also the plant shown in Figure 251.

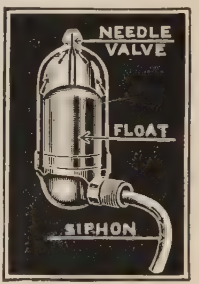
Steam exerts pressure. The steam heating plant differs from the hot-air and hot-water systems in its method of transferring the heat of the fire to the various rooms. You have learned what makes water and air circulate through a heating system. Let us now determine how steam is sent through the pipes of the system.

Experiment 65: What causes the steam to circulate through the pipes?

Place about one inch of water in a test tube. Stopper the tube with a cork, but do not insert the cork tightly. Heat the tube with a small flame. What happens shortly after the water begins to boil?

In the steam heating plant the steam is forced to circulate through the pipes and radiators by *pressure* produced in the

boiler. How does the steam exert pressure? As the water changes into steam, it expands hundreds of times, forcing the molecules of steam above the water in the boiler closer and closer together so that the steam is compressed. This steam exerts pressure when compressed, because of the motion of the molecules. The molecules are moving, and strike the walls of the containing vessel with great speed. Millions and millions of them bombard the walls. As the steam is compressed, more molecules are forced into the same space, and the number striking the walls increases. This steady bombardment is like a stream of water playing on the side of a building. So many particles of water strike at a given time that a steady pressure is exerted against the wall.



Courtesy Marsh & Co.
Fig. 253. Air Vent for Radiator

The steam heating plant (Figure 252) differs but little from the hot-water plant. Steam is carried to the radiators through the risers. In the radiators the steam condenses into water, giving up its heat. The water is carried back to the boiler by a return pipe. No expansion tank is necessary in this system. Why? Each radiator is fitted with an *air vent* (Figure 253) to allow the escape of the air which is driven from the water as it is heated, and from the pipes and radiators. When steam enters the radiator, the air is driven toward the air vent and escapes. As soon as the steam reaches the valves of the air vent, the heat from the steam automatically closes the valve, keeping the steam in the radiator. The condensed steam flows back into the radiator through the siphon. The radiator warms the room in the same manner as that of the hot-water heating plant.

Exercise 11. Make a drawing of a steam heating plant. Indicate the direction of the steam through the pipes. Show how the room is heated by the radiator.

Exercise 12. Why is steam always used in the heating of large buildings where long horizontal pipes are used?

PROBLEM 5: HOW IS GOOD VENTILATION SECURED?

The ill effects of "bad air" are not caused by too much carbon dioxide. You recall (Unit V) that air expelled from the lungs differs in four ways from ordinary air. (See page 153.)

Exercise 13. What changes take place in air during breathing?

Years ago it was thought that the bad effects resulting from poor ventilation were due to the addition of carbon dioxide to the air during breathing, and the decrease in the amount of oxygen in the air. Recent experiments show that the ill effects from bad air are not due to these causes.

Fig. 254. Window Open at Top and Bottom

There are several reasons why air becomes bad. If you have ever been in a crowded, poorly ventilated room, you have probably noticed the presence of bad odors. These odors may be due to several causes, such as decayed teeth, a disordered stomach, or unclean bodies and clothing. The temperature of the air in the room also increases because of the heat from the bodies of the people present. Since exhaled air contains a large amount of moisture, the humidity of the room also increases. Scientists now believe that these three changes in the air—foul odors, high temperature, and high humidity, are the real causes of bad effects from poor ventilation. A good system of ventilation will keep the temperature and humidity of the air from becoming too high and will keep the air clear of bad odors.

The temperature of the air should be correct. In Unit VI you learned how the body regulates its own temperature. (See page 175.) The temperature of a room should always be such that the heat-regulating mechanism of the body shall have as little to do as possible. If the temperature of the air is too low.

the body must adjust itself to this condition by decreasing the amount of blood in the skin or by burning more food. Why? If the temperature of the air is too high, the body must pour more perspiration on the skin and send more blood to the skin. Why? These changes require energy which must be taken from the body. Careful experimentation has shown that the best temperature for all-round bodily comfort and efficiency is from 68 to 70 degrees Fahrenheit.

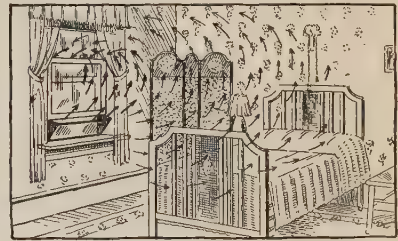


Fig. 255. A Window-Board

The window-board prevents the current of air from flowing directly on to the bed and thus exposing the sleeper to a draft. Such devices may be made of glass, wood, or metal.

The proper humidity should be maintained. When the humidity is very high, but little perspiration can be evaporated from the skin, and, as the body temperature rises, a feeling of discomfort is produced. On the other hand, the humidity of the air may be too low. This is particularly true in the winter time when the cold dry air from out of doors is brought into the house and warmed. Why? (See page 52.) Dry air absorbs moisture very rapidly. The linings of the nose, throat, and bronchial tubes must at all times be moist. Dry air will cause this moisture to evaporate rapidly from these linings, and so produce irritation. For this reason it is generally necessary to add moisture to the air during the winter months. In case the heating system does not provide enough moisture, pans of water can be placed on the stoves or on the radiator.

Rooms and houses may be ventilated by windows. A very common method of ventilating rooms is by windows (Figure 254). When the temperature of the air outside of the room is less than that inside, a convection current will be produced as the cold air enters and forces out the warmer air. Since the warmer air is near the ceiling, the window is opened at

the top as well as at the bottom. Why? In case the temperature of the air inside of the room is the same as that outside, no convection current will be produced, and no air will enter unless there is a breeze outdoors. To use this breeze several windows must be opened so that the air may sweep through the room. Extremely strong drafts should be avoided, however, especially when one is not moving about.

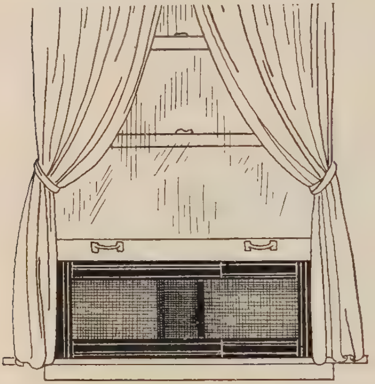


Fig. 256. Window Fitted with Cloth-Covered Frame

To secure ventilation and at the same time to prevent strong drafts from blowing directly on one, it is advisable to use a window-board (Figure 255) which will cause the incoming air to be deflected upward. A frame fitting the window and covered with a cloth (Figure 256) will accomplish the same result and at the same time will prevent the entrance of dust. The effect which one should try to produce is that of a gentle current which will change the air often enough to provide about thirty cubic feet of fresh air a minute for each person.

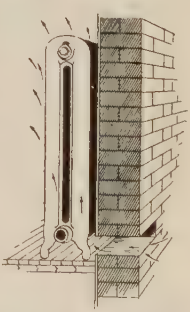
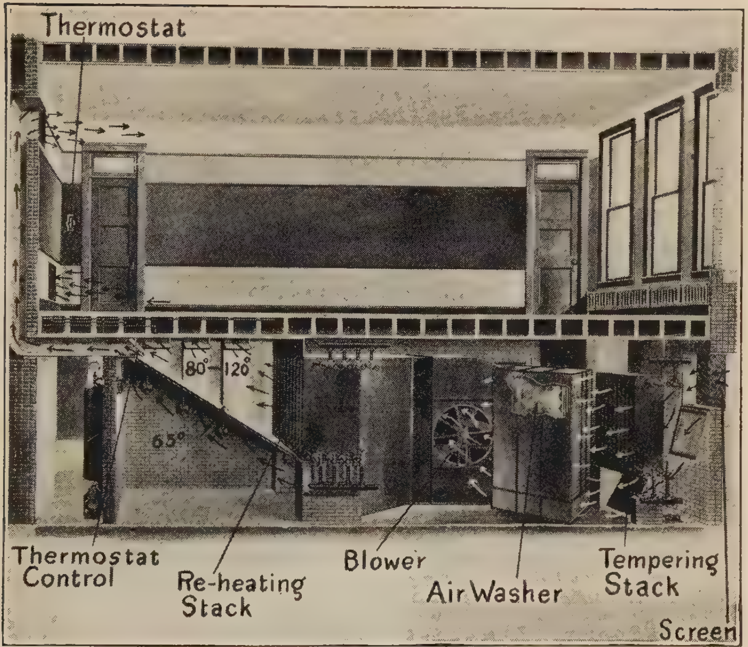


Fig. 257. Ventilating a Building Heated by Hot Water or Steam

Why does the air enter the house?

Heating devices also furnish ventilation. There are several other systems of ventilation used in connection with the heating system. The chamber of a hot-air furnace receives fresh air from a pipe which passes outdoors (Figure 243). Pans of water may be placed in the chamber to increase the humidity. Where steam or hot-water systems are used, holes are sometimes cut through the wall behind the radiator (Figure 257). Fresh air may thus enter and be warmed.



Courtesy American Radiator Co.

Fig. 258. Fan System of Ventilating and Heating a Large Building

The air enters through the screen at the right and passes through the tempering stack, which consists of several coils of pipes containing steam. These hot coils raise the temperature of the air. The air is humidified and washed as it passes through streams of water in the air washer. The blower forces part of the air through the re-heating stack, which heats it to a temperature of from 80° to 120°. Part of the air from the blower passes under the heating stack and remains at a temperature of 65°. The thermostat control automatically mixes the reheated air and the air which passes below the stack to keep a constant temperature of 70°.

Exercise 14. Make a drawing of a room with the inlet for warm air near the ceiling and the outlet near the floor on the same side of the room. Show by means of arrows the direction of the air currents in the room.

Large buildings must have special ventilating systems. Fan or blower systems for ventilating and heating are used in

large buildings, especially where many persons are assembled, as in factories, theaters, and schools. The fan is placed in the basement and takes the air after it has passed over heating coils (Figure 258), forcing it to the different parts of the building. This method greatly increases the volume of fresh air supplied. The air may be washed and humidified by forcing it through a spray of water. By warming the air to the proper temperature before it passes through the water-spray, more water will be evaporated into the air, and the correct humidity may be obtained.

Exercise 15. Draw a room with one window open at the bottom. Show by arrows the direction of the air currents in the room.

Exercise 16. Draw a room with one window open at the top and also at the bottom. Show by arrows the direction of the air currents in the room.

Exercise 17. Which of the two methods used in Exercises 15 and 16 secures the better ventilation? Why?

Exercise 18. What method of securing ventilation is used in your house?

Exercise 19. What method of securing ventilation is used in your school? If you have a fan or blower system, arrange with the engineer or janitor to let you examine it.

Review Exercise on Unit IX. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit IX and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT IX

1. Why do you get warm if you are sitting in front of a window when the sun is shining brightly, while the windowpane is not heated?

2. Why does your back feel cold when you stand facing a fireplace?

3. Why does not the smoke come up the registers in a hot-air system?

4. Sometimes it happens on very cold mornings that a room will not heat even if the register is open. Explain why this is true and how you would remedy it.

5. Why will a steam radiator warm up faster if the valve in the air vent is unscrewed slightly?

6. How does a green-house "trap" the heat of the sun?

7. Which is the hotter: water which has been boiling an hour, or water which has been boiling ten minutes? Give a reason for your answer.

8. Why are furnace pipes often covered with asbestos?

9. If you open a door between a warm room and a cold one, which way will a candle flame be blown if the candle is held near the top of the doorway? Give a reason.

10. Why, when the temperature of the two is the same, does linoleum feel colder to the touch than a rug?

11. If a piece of paper is wound tightly around an iron rod and is then held for an instant in a Bunsen-burner flame, it will not be scorched. If it is wrapped around a wooden rod and held in the flame for an equal length of time, it will be scorched. Explain.

12. Why should the space between the walls of a fireless cooker be filled with sawdust instead of being filled with air alone?

13. Why are stoves made of iron?

14. How do you account for the shape and construction of a radiator?

15. Why are the hot-air and hot-water heating systems sometimes called the "gravity" method of heating?

16. How can the temperature of a room be regulated in each of the different methods of heating a room?

17. Make a survey of your community to find the different types of heating systems which are used.

18. Find on furnaces the names and addresses of the manufacturers, and write for booklets descriptive of the operation and construction of the furnaces. Report to the class your findings.

19. How do oil heating plants operate? Write to companies which manufacture these devices for their descriptive booklets or examine an "oil-heater." Explain how it works.

UNIT X

MATERIALS FOR CONSTRUCTION

Preliminary Exercises

1. Make a table, as shown below, giving as many different kinds of materials as you can which are used in making your house and the articles in it. Under "Natural or Artificial" use "N" or "A" to indicate whether the material is found free in nature or is manufactured from other materials. (Do not include clothing materials.)

Materials I Know

NAME OF MATERIAL	NATURAL OR ARTIFICIAL	PROPERTIES WHICH MAKE MATERIAL USEFUL
Iron	A	Non-combustible, good conductor of heat, strong.
Wood	N	Easily shaped, beautiful grain and finish.

2. Make a table of metals which you know, and opposite each indicate one important property and one important use.

Metals I Know

METAL	PROPERTY	USE
Iron	Conductor of heat	Heating devices
Copper	Does not rust	Water spouts

3. List the ways in which man's use of building materials has changed his way of living.

4. What different materials were used by primitive people in building their shelters?

5. Why does glass find so many uses?

6. Why are stoves made of a metal like iron?

7. Name the kinds of rock or stone which are used for construction.

8. What reasons can you give for painting an iron fence?

9. What are the principal kinds of wood found in your region? List them, and following each, state for what it is used.

Fig. 259. Tents and Tepees of Primitive People

10. Write a short story telling how some building material is prepared for use.

THE STORY OF UNIT X

When you look around and see so many different objects, you wonder where they all come from and of what they are made. There seems to be no end to man's use of different materials for constructing his houses, barns, factories, and other buildings; for making his tools and machinery; for providing means of travel and transportation; for making the thousand-and-one things which he needs for his comfort, efficiency, and enjoyment.

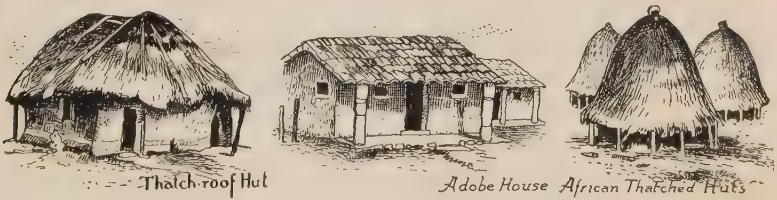


Fig. 260. Homes Unknown to Most of Us

In early days man used only materials which nature provided, such as straw, skins, wood, clay, bones, and stones. It was of these materials that he made his crude buildings (Figures 259-261) and primitive tools. He had only to collect them

and, perhaps, to shape them into usable forms. From stones he made his arrows, skinning tools, axes, grinding stones, and other devices for procuring and preparing his food, for shaping wood to build his shelters, and for defending himself against his enemies (Figure 262). Later he discovered in the earth certain metals which he shaped into many different forms.

Fig. 261. Primitive Homes in Different Climates

By the use of fire he made great progress in obtaining metals from their ores and in manufacturing all sorts of devices from these metals. Because we now use metals for so many purposes, we sometimes speak of the present age as the "metal age," as contrasted with the so-called "wood age" and "stone age" of past centuries.

The preparation of building materials is one of the world's greatest industries. Millions of people are daily working in mines, in stone quarries, in factories, and in fields and forests, where they collect, shape, and manufacture innumerable objects to satisfy our needs and comforts. These millions of workers are needed in order that we may have stones, cement, mortar and plaster, brick, tile, pottery, glass, iron and steel, many other metals, rope, wood, and hundreds of other things. And every year new materials come into use. The number of these different materials is so great because we are constantly searching for those which have certain properties, or qualities, best fitting them for particular uses.

There are two kinds of properties, physical and chemical, which determine the use of materials. The *physical properties*

are those by which you recognize a material without changing it into some new material. For example, materials may be recognized by and may depend for their use upon properties like the following: color, hardness, strength, transparency (can you see through it?), malleability (can it be hammered

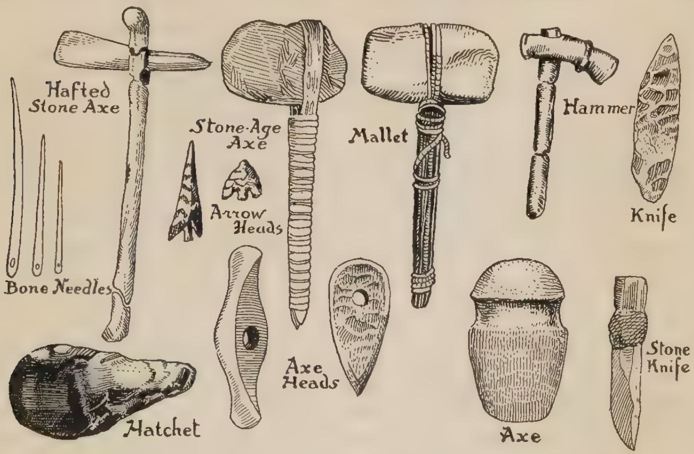


Fig. 262. Tools of Past Ages

Such tools are crude as compared with tools of the present day, but it required great skill to shape them and to fasten the handles to some of them.

into sheets?), conductivity of heat (can heat travel through it?), conductivity of electricity (can electricity pass through it?), and *physical state* (is it solid, liquid, or gaseous?).

The *chemical properties* are those characteristics which a material shows when it undergoes chemical changes. Thus, wood decays when exposed to air and moisture; iron rusts unless protected from the air; wood burns; cement and stone are non-combustible; brass is acted upon by salt water and becomes porous and weak; some stones crumble as a result of the chemical action of the air. The *durability* and use of a material thus depend largely upon its chemical properties.

It is because of these chemical properties that all kinds of *preservatives* and protective substances must be used to increase the durability of certain materials. Such preservatives make possible the use of materials which have desirable physical properties. For example, iron, which is strong and a good conductor of heat, may be used for locomotive boilers or other heating devices if it is protected from rusting by a coat of paint. Or, as another example, wood may be very durable for interior construction, but will decay very rapidly out-of-doors unless protected by the use of creosote or paint.

There is one other factor, besides the properties of a material, which determines how widely it is used: unless a material is available in large quantity and at a relatively low cost, it must give way to a cheaper and more plentiful material. For this reason brick, stone, cement, and tile are being used instead of wood for many purposes. While the properties of these materials are a large factor in determining their greater use, it is also true that in some places these materials can be obtained or manufactured more cheaply than wood can be shipped and prepared. A striking example of this is the increased use of paper and cardboard for making boxes, which were formerly made almost entirely of wood.

The more important construction materials are shown in Table X. Wood is listed first because it is still used in such enormous quantities. Then follow the principal groups of materials with some of the more common examples of each group.

Table X. Materials for Construction

Wood products	Boards, planks, shingles, blocks, paper
Building stones	Granite, sandstone, limestone, marble, slate
Clay products	Brick, tile, pottery
Lime products	Mortar, plaster, terra cotta
Cement products	Cement, concrete, cement mortar
Glass products	Window glass, bottle glass, plate glass
Iron products	Iron, steel
Other metals	Copper, aluminum, lead, zinc

The amounts of different materials which were used in the construction of one large building are:

16,000 tons of steel	3,400 windows
13,000 tons of stone	162 miles of wire
33,000 tons of tile	71 miles of wire conduit-pipes
7,000,000 bricks	300 carloads of marble
200,000 bags of cement	

Think of the labor necessary to prepare, manufacture, ship, and build these materials into a sky-scraper.

PROBLEM 1: HOW IS WOOD PREPARED FOR BUILDING PURPOSES?

Wood is the most common building material. Everywhere about us we see things made of wood. The lumber industry is one of the most important in the United States. Not only is wood used for building houses and for making furniture, but it also finds many other uses, such as making boxes, sidewalks, railroad cars, vehicles, fences, pavements, and handles for tools. The table below will give you some idea of the large quantity of wood used in certain years from 1880 to 1924.

TABLE XI. LUMBER CONSUMPTION IN THE UNITED STATES*

YEAR	BILLIONS OF BOARD FEET	YEAR	BILLIONS OF BOARD FEET
1880	18	1905	47
1885	21	1910	44
1890	23	1915	37
1895	30	1920	33.8
1900	35	1924	37.1

*Figures are approximate, being estimated from graph in the U. S. Department of Agriculture, Bulletin 1119.

The table shows the number of board feet of lumber used. (A "board foot" is a board one inch thick, twelve inches wide, and twelve inches long.) Roughly, about 70 per cent of the total amount of lumber consumed is used for general building

purposes. The remaining 30 per cent is used for making furniture, fences, boxes, paper, and other special articles.

New ways of preparing lumber have taken the place of the old ways. For many years man prepared wood for different uses without the aid of machinery. The trees were felled with axes, and then cut into logs. The logs were used mainly for building crude but attractive houses, and for making roadbeds through swampy regions. Sometimes the logs were hewn with wide axes until they were square, or split into various shapes and used for fuel, rail fences, clapboards, and shingles (Figure 263). Later the straight saw came into use, and the trees were more easily felled and cut into proper lengths. Then came the circular saws, which made still easier and more rapid the sawing of the logs into posts, boards, shingles, and other shapes. With the coming of circular saws many saw mills were built in the forests. These sawmills were moved from place to place as the supply of timber made necessary. At the present time most of the logs are floated down stream to the mills (Figure 264), or hauled to railroad cars to be shipped to cities and towns where there are the sawmills.

Fig. 263. Hand-Hewn Lumber

This cabin was built in 1852 in the Sierra Nevada mountains by California gold-seekers. The shingles, or "shakes," have been worn until they are almost as thin as paper.

The rough-sawed lumber must be dried, or *seasoned*, before it can be used for finer construction. To season it, the lumber is stacked with air spaces between the boards and allowed to stand until the water it contains evaporates. Stacking the

lumber keeps it straight while it dries. Sometimes the green lumber is placed in large ovens, or *kilns*, where it is heated to evaporate the water. This requires less time than the natural drying or seasoning process. The dry lumber will not warp and lose its shape.

The board lumber for finishing the outside of houses, for making furniture, refrigerators, window-sashes, and similar finished products, is sent through a *planing machine* which

Courtesy U. S. Forest Service

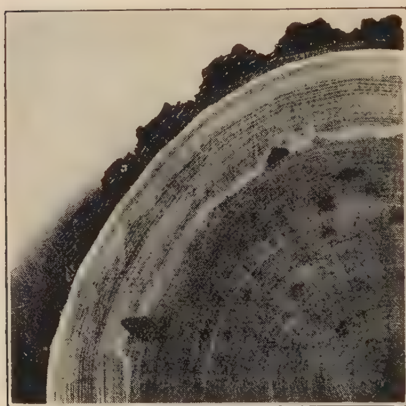
Fig. 264. Floating Logs to the Sawmill

Millions of board feet of lumber will be sawed from these logs. The workmen are engaged in breaking up the jam so that the logs may float downstream.

removes the rough surface. When a fine finish is desired, the lumber may be sandpapered, or *surfaced*, until it is smooth enough to be painted or stained.

You see that four important processes are necessary in the preparation of wood for finer building purposes: (1) cutting and logging the trees; (2) sawing the logs; (3) seasoning the lumber; and (4) finishing the boards.

The grain in lumber depends upon the growth of the tree and the method of sawing. All trees grow more rapidly in the spring than they do in the late summer or fall. When the growth is rapid, the cells of the wood are large and loosely



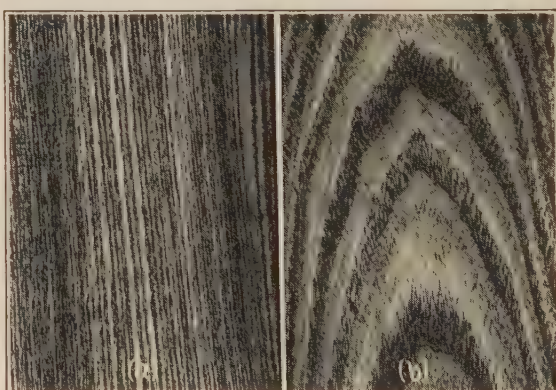
Courtesy U. S. Forest Service

Fig. 265. Annual Rings

The picture of the log is so small that you cannot count the pairs of layers, but you can see many light and dark rings.

arranged. During the summer the cells grow slowly, are small, and arrange themselves very compactly, forming a dark, dense layer. No growth takes place in the winter. By examining the end of a log, one can see these alternate layers of dark compact cells and lighter loose cells. Each pair of layers of this kind shows a year's growth from the center outward, as shown in Figure 265. The rings are called *annual rings*, and from the number of them you can tell about how old a tree is.

Since the layers are not of equal depth in all parts of the tree, cutting across these unequal layers results in the different *grains*, or patterns, which you see in many boards. If a log is cut as shown in Figure 266 (a) (radial-sawed), the grain will not be the same as if it is cut as shown in Fig-

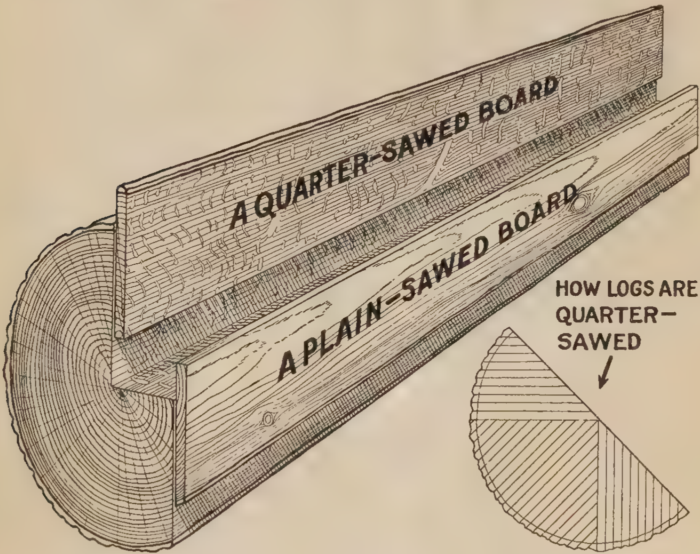


Courtesy U. S. Forest Service

Fig. 266. Boards from an Ash Log

The board at the left was cut by sawing through the center of the log; the board at the right was sawed from the log as shown by the plain-sawed board in Figure 267.

ure 266 (*b*) (tangential-sawed). Figure 267 shows the grain of two oak boards, one tangential-sawed and the other quarter-sawed. The wood of the *medullary rays*, which extend from the center of the tree outward, has a different structure from that of other parts of the log (Figure 268). In hardwoods, like oak, these medullary rays add to the beauty of the lumber,



Courtesy U. S. Forest Service

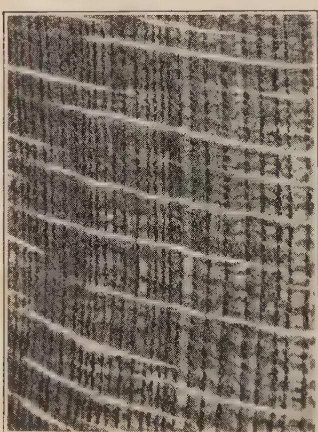
Fig. 267. Two Methods of Sawing a Log

At the bottom is a tangential, or plain-sawed, board. Note the grain caused by sawing across the dark and light sections of the annual rings. Compare this with Figure 266 (*a*). At the top is a quarter-sawed board. Observe in the inset how the log is cut into quarter-sawed boards.

especially in quarter-sawed boards. Softwoods do not have the beautiful grain of the hardwoods.

The terms "hardwood" and "softwood" are not well chosen. They refer to the method of growing and to the structure of the tree rather than to the hardness of the wood. However, as a rule hardwood is stronger and more durable than softwood. Hardwoods, like oak, ash, and maple, are much used

in building heavy structures and in making furniture, flooring, and doors. The softwoods, such as pine and cedar, are extensively used to make boxes, shingles, telegraph and fence posts, and window-sashes.



Courtesy U. S. Forest Service

Fig. 268. Medullary Rays

The white horizontal streaks are the medullary rays seen at the end of a log. Note how they appear on the side of the quarter-sawed board in Figure 267. How many pairs of rings can you count in this picture?

Wood has certain advantages and disadvantages. Wood is lighter than most other construction materials. It is easily shaped into different forms. The natural color and beautiful grain of wood cannot be duplicated in any other building material, except perhaps in the finer varieties of marble and expensive manufactured materials. Wood is not a conductor of heat or electricity and can, therefore, be used for making handles of heating and electrical devices, for refrigerators, telephone and telegraph poles, and handles to different tools and farm implements. The lightness of wood is also of importance in most of the cases mentioned.

The disadvantages of wood for some uses are so great that other materials have been substituted for it. Wood decays rapidly when moist and exposed to air. Another great objection to the use of wood is its combustible nature. Because of this property, fireproof materials like metals, stone, cement, brick, tile, and terra cotta have been substituted for it. The development of machinery has made it necessary to use iron and other metals to a large extent. Not only must the materials of which machinery is made be fireproof, but they must have great strength and weight. The greater strength and durability of these substitute materials indicate another disadvantage in the use of wood.

Exercise 1. Make a summary of the principal steps in preparing wood for use.

Exercise 2. Make a table showing the advantages and disadvantages of wood as a building material.

Exercise 3. Examine the pieces of wood in the different articles of furniture in the school room and at home, and see if you can tell if they are quarter-sawed or tangential-sawed.

Exercise 4. Go to a lumber-yard and ask for small pieces of various kinds of wood sawed in different ways. Label them on one side. Examine them until you think you can recognize them.

Courtesy Boutwell, Milne and Varnum Co.

Fig. 269. A Granite Quarry

The huge block has been split by the wedges. The cable is fastened around this block which is about to be lifted from the quarry by means of a large hoisting-crane.

PROBLEM 2: WHAT ARE THE CHARACTERISTICS OF THE PRINCIPAL BUILDING STONES?

The combustibility, rapid decay, great cost, and lack of strength of wood as a building material have led to the use of stones and other materials obtained from the earth. Especially in large cities, safety from fire requires the use of non-combustible materials. Nearly $100,000,000 worth of stone is used in construction each year in the United States.

There are five important building stones. *Granite, sandstone, limestone, marble,* and *slate* are found in various parts of our country. The ease with which they can be *quarried* (Figure 269), cut, and transported, and the fact that large

deposits are found near cities where they are used, have made them cheap. They wear better than wood, and can withstand the strain of greater weights. For foundations and large buildings, they are especially fitted. Most of them are durable under all weather conditions. Can you distinguish one from another?

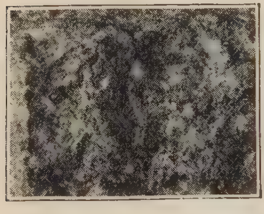


Fig. 270. Granite

In this sample, or specimen, the particles of the different materials are so small that it is difficult to see them.

Experiment 66: What are the properties of granite, sandstone, limestone, marble, and slate?

(*a*) Examine pieces of granite. In the coarse granites you can see distinctly three kinds of materials. The white glass-like crystals are *quartz*. The dull white-to-salmon-colored masses are *feldspar*. Scattered between the quartz and the feldspar are black particles of *mica* (isinglass). Sometimes these materials are very small and so thoroughly mixed that each cannot be recognized distinctly (Figure 270). The colors of the quartz and feldspar vary in different granites because of the presence of impurities.

(*b*) Examine pieces of sandstone (Figure 271). Can you see the sand particles? Can you break away small grains of sand? Observe the layer-like formation of the stone and the color of several samples. This color is due to impurities like those in the quartz or feldspar of granite. Do you think that sandstone can be cut and chiseled as easily as granite? Why?

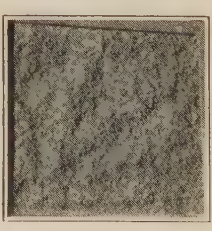


Fig. 271. Sandstone

Grains of sand form a hard stone when compressed and cemented together in this way.

(*c*) Examine pieces of limestone (Figure 272). Note that it has practically the same appearance throughout, although the colors of different samples may vary from white to black. Is the limestone easily broken or scratched? Does the limestone have a layer-like structure? Allow a few drops of hydrochloric acid to fall on a piece of the stone. What happens? The bubbles are carbon dioxide. (Try the acid test on sandstone and granite. Result?)

(*d*) Examine pieces of marble (Figure 273). Note the *crystalline* appearance. Drop acid on the marble. Do bubbles appear? Is the marble as easy to scratch as limestone? Do you think it can be cut as easily? Has it a layer-like structure?

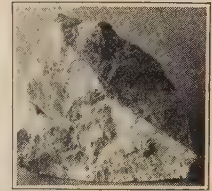


Fig. 272. Limestone
Unlike the sandstone, separate particles cannot be seen in the limestone.

(*e*) Examine pieces of slate (Figure 274). Note the smooth surface. Try the acid test. Try to break the slate, and observe that it splits into layers.

Exercise 5. Summarize the information you have gained from Experiment 66.

Granite is the strongest and most durable of the building stones. The quartz in it is very hard; this makes it difficult to cut or chisel the granite into different shapes. The great strength and durability of granite, the ease with which it can be highly polished, and the variety of colors of different kinds make it especially useful for large buildings, monuments, and tombstones. It is so compact that not enough water can enter between the particles to cause the stone to break when the water freezes and expands. For this reason you may often find sharp projections and faces of granite in mountainous regions, which have withstood the weather for many years. Granites are so strong that a block of this stone one cubic inch in size can bear a pressure of from 12,000 to 21,000 pounds without breaking.

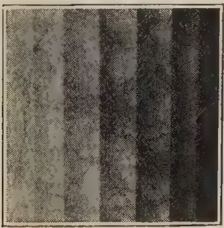


Fig. 273. Marble
This section of a pillar shows the markings that make marble so attractive.

Sandstones are made of sand which has been compressed into solid rock. The stone is easily

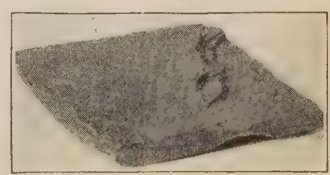


Fig. 274. Slate
You can see the layer-like structure of the stone and one of the cracks along which it splits.

quarried and cut. Why? Most varieties are not strong enough for heavy building purposes and do not last long under constant wear. You have undoubtedly seen steps made of sandstone which were in part worn away by use. Sandstones of many colors and degrees of hardness are found in the United States. The brownstone of Connecticut and New Jersey, the

Courtesy Indiana Limestone Quarrymen's Association

Fig. 275. A Limestone Quarry

The steam channeling-machines cut the solid rock into huge blocks. The block which is being lifted by the derrick weighs over 10 tons. This quarry is at Bedford, Indiana.

drab-colored Berea sandstone of Ohio, the light drab, or dove-colored, Waverley sandstone of southern Ohio, the dark purplish-brown coarse sandstone of the Lake Superior region, and the lighter colored sandstones of St. Genevieve, Missouri, are among the most important deposits.

Limestone is probably the most common of all natural building stones. It varies in color from nearly pure white to gray and black. It finds many uses other than ordinary building purposes, such as in the manufacturing of cement, fertilizers, glass, and lime, in making roadbeds for highways and railroads, and for freeing iron from its ore. It is usually very hard and cannot be easily cut. The gray-colored stone

is used extensively for trimming brick buildings. The largest quarries are found in Ohio, Illinois, Indiana, and Vermont (Figure 275).

Marble is the most beautiful of all building stones. The pure white and the rich colors in different varieties give the

Underwood and Underwood

Fig. 276. A Beautiful Marble Building

This is a view of the auditorium at the Arlington National Cemetery.

stone extensive use in constructing fine buildings (Figure 276). The white, gray, brown, reddish, and blue-colored varieties are particularly ornamental, although the white is easily stained. Its structure, or texture, allows it to be highly polished, but makes it hard to cut and chisel. The Vermont quarries are the most famous in this country.

Slate is used principally for roofing and blackboards. The layer-like structure of the stone makes it possible to split the stone into slabs. These slabs may then be surfaced until they are quite smooth. The stone is fairly hard, but does not withstand great wear. The principal slate quarries are found in Pennsylvania, New York, and Vermont.

Exercise 6. Examine different stones used in constructing your schoolhouse and other buildings. For what parts of the buildings is each kind of stone used? Why?

Exercise 7. Make a collection of pieces of building stones, and see if you can recognize the different stones described in this problem.

Exercise 8. Why are steps made of sandstone worn down rather rapidly?

The building stones were formed in different ways. The process of formation of these building stones explains the differences in their structure and appearance. Granite is an *igneous* rock (igneous refers to fire). It was formed when the different rock materials which are in it, melted, mixed together, and then cooled. It therefore shows no layer-like structure. Sandstone and limestone are called *sedimentary* rocks. Sandstone was once fine sand deposited in a body of water and later covered to a great depth with other materials, like mud or limestone, which compressed it into a hard stone. Similarly, limestone was formed in layers when millions and millions of small water creatures died and their skeletons sank to the bottom of the water to be covered with other deposits and pressed into solid stone. Marble and slate are known as *metamorphic* rocks. They were formed from sedimentary rocks which were covered by deep layers of other materials and then subjected to great heat, as well as to the pressure of the layers above. The great heat and pressure changed limestone to marble, and changed *shale*, that is, compressed clay deposits, to slate.

Exercise 9. Make a table in which you summarize the properties, uses, and formation of each of the five building stones.

A COMPARISON OF BUILDING STONES

KIND	PROPERTIES	USES	FORMATION
Granite Sandstone etc.			

PROBLEM 3: HOW IS CLAY USED FOR CONSTRUCTION?

Clay deposits are so common that for centuries great amounts of clay have been used in many different countries to make *brick*, *tile*, and other building materials, and also *pottery*. Parts of buildings made of sun-baked clay are still found in Egypt and in the valleys of the Euphrates and Tigris rivers. The adobe buildings of Mexico and of certain Indian tribes in the United States are other examples of the durability of unburned bricks (Figure 277).

Ewing Galloway

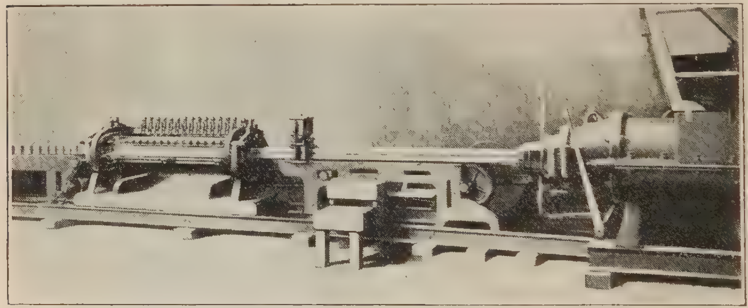
Fig. 277. An Adobe Building

Indians in Colorado enjoying a holiday at home on their adobe houses.

Clay is used in making bricks. The bricks of today are made of clay, sandy clay, or *marls*. When bricks of pure clay are molded and baked, they shrink, crack, and warp; therefore, sand, ashes, or cinders are sometimes added to overcome these defects. The sandy clays are composed of sand and clay. If too much sand is present in the bricks, they will be brittle. Pure clay must be added to such sandy clays until the proper mixture is obtained. Marl is a mixture of clay, sand, and a loose form of limestone. The limestone makes the brick very hard and non-porous when baked. There are also present in the marl small quantities of iron oxide, lime, and soda. It is the iron oxide which gives the brick its red color. Lime clays or marls which contain no iron oxide and no plant material form white bricks when they are baked.

Experiment 67: How can bricks be made?

Obtain some clay and moisten it enough to make a *plastic* mass. Shape this into small brick forms. Place some in the bright sun and others in a hot bake-oven for several hours. Examine the bricks when cold. You see that they are not very hard. The heat of the sun or the bake-oven is not great enough to make them hard. Now place them on a small pan over a burner or in the firebox of a stove or furnace and leave them for several hours. Remove them and see how they have changed in appearance and texture.



Courtesy Metropolitan Brick Company

Fig. 278. A Brick-Stuffer and Cutter

At the right is the brick-stuffer forcing out the long white bar of stiff clay. The machine at the left cuts the bar into bricks, which may be seen at the extreme left.

In making bricks, the correct mixture of clay and other *ingredients* must first be prepared. From this point on, three different processes of shaping the clay are used. In one process the clay is moistened until quite plastic and is then pressed into molds. As it dries it contracts slightly, and the bricks can be removed and placed in ovens to be thoroughly dried. These are soft-clay bricks and are much like those of early times. A second process is called the stiff-clay process. The clay, properly mixed, is moistened. The plastic mass is placed in a big container that works like a sausage-stuffer (Figure 278). The clay is forced through a rectangular hole and forms a long bar-shaped mass. The

Courtesy National Paving Brick Manufacturers Ass'n.

Fig. 279. A Brickkiln

Through the door the stack of bricks inside the kiln may be seen. Around the sides of the kiln you see small openings where fires are built. The hot gases from the fire pass into the kiln, through the spaces between the brick, and out the chimney at the top.

Courtesy Metropolitan Brick Company

Fig. 280. Discharging the Brickkiln

The workmen enter the kilns and remove the baked bricks, after these have been put to hours of baking and more hours of cooling.

bars are then cut into proper lengths. These unburned bricks are dried and placed in kilns, or ovens, where they are heated, or *fired* (Figures 279 and 280). In a third process, known as the pressed-brick process, the clay is ground into a fine powder and moistened just enough to make the powder damp. This is placed in molds and compressed into brick shape by powerful presses, called hydraulic presses, and then baked.

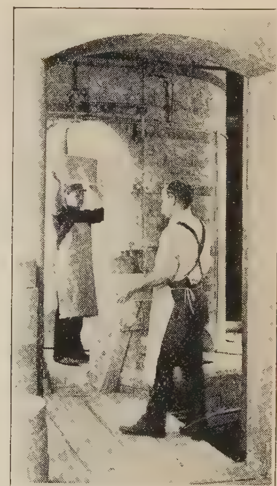
Courtesy Rookwood Pottery

Fig. 281. The Potter at His Wheel

By means of a foot-pedal the flat circular stone is rotated, turning with it the soft clay which is being shaped into a vase. Wet fingers and a very skillful touch and pressure transform a lump of clay into a beautiful vessel.

Tiles are similar to bricks in composition. The ordinary building tile and drainage tile are made by molding the clay into the proper shape and then baking. The beautiful ornamental tiles for floors and wall decorations are also made of clay and baked, but various compounds are added before baking to give color. Often the plain tile is dipped into a *glaze*, which is a mixture of water and some color-giving compound, and is then baked a second time. The composition of the glaze not only determines the color, but it also determines the smoothness or roughness of the surface of the baked tile. By selecting the proper materials and baking them at correct temperatures, a large variety of materials like pottery, china, porcelain, and terra cotta can be made.

Pottery is made of clay. The clay that is used for pottery such as china and porcelain is very pure. It is free from iron compounds which would cause it to be colored when baked. In preparation the dry clay is ground to a very fine powder and then mixed with enough water to make it plastic. It is then shaped into plates, saucers, vases, or any desired form. The making of beautifully shaped vases is a fine art and must be done by hand, as shown in Figure 281. The simple forms, such as saucers and plates, may be shaped by machinery.



Courtesy Rookwood Pottery

Fig. 282. A Pottery Kiln

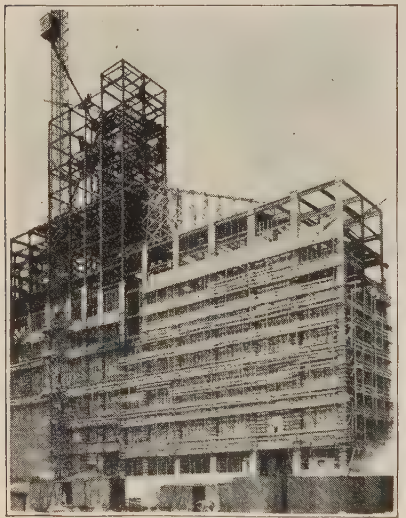
These men are "stacking" the kiln with the unbaked pottery. As you can see, the pottery is placed in large containers. These are made of fireproof clay.

After the forms are made and have dried for a short time, they are placed in kilns (Figure 282). Here they are heated to a high temperature for several hours and then allowed to cool in the kilns. When the objects are removed from the kiln, they are hard but porous articles, called *bisque.* This bisque is now glazed. When the article has dried, it is again fired in the kiln, this time at a very high temperature. The resulting product is very hard and white, and has a glass-like surface. If it is to be decorated, certain coloring materials are used to place the design on the article, and it is then fired for a third time. The coloring materials melt into the glaze and give the desired color as a permanent part of the glaze. If you ever have an opportunity to make a trip through a pottery, you should be sure to do so, for pottery-making is a most interesting industry.

Exercise 10. State the differences in the composition, manufacture and properties of brick and tile; of brick and pottery. State the similarities.

PROBLEM 4: HOW IS CEMENT MADE AND USED?

Probably no building material has been substituted for wood to as great extent as *cement*. In recent years buildings, bridges, sidewalks, piers, fence posts, and roads, have been made of *concrete*, which is a mixture of cement, sand, and gravel or crushed stone. This concrete becomes as hard as stone. It is very durable and can be used under water as well as above ground. For large buildings, bridges, and other structures which must bear heavy weights and great strains, the concrete is reinforced with iron rods, wire, or steel beams (Figures 283 and 284).



Mississippi Valley Structural Steel Co.

Fig. 283. Under Construction

The steel framework is ready. Wooden forms for the concrete have been built around a large part of the framework. Wet concrete is being placed in the forms by means of the pipe which leads from the derrick at the top.

Cement is a combination of lime and clay. Cement is usually made by heating together a mixture of the proper amounts of clay and limestone, although there are some natural rocks which contain the right proportion of these two substances. When the artificial or natural mixture is heated to a high temperature for a long time, the clay and the lime from the limestone combine to form a compound. This hard compound is then ground into a fine powder forming the cement which we use.

Most cement is used to make concrete. When it is used for construction purposes, cement is mixed with sand,

gravel or stone, and water to make concrete. The wet, "mushy" concrete is placed in forms made of wood until it becomes hard or "sets." The wooden forms are then removed. The "setting" or hardening is due to the action of the water upon the cement. The water is absorbed and combines with the cement to form a new compound so hard that it is called artificial rock.

Mississippi Valley Structural Steel Co.

Fig. 284. Completed Building

The building shown in Figure 284 has been completed. The wooden forms are removed. Concrete covers the steel frames, forming a reinforced-concrete, fireproof building.

In making concrete, four things must be considered. First, the mixture must be thoroughly wet or there will not be enough water to combine with the cement to form the artificial rock. Second, if too much water is used in mixing the concrete, it may wash the cement away from the other parts of the mixture, leaving only sand and gravel. The mass will then not harden properly. Third, there must be a correct proportion of cement, sand, and gravel or stone. If there is too much cement in the mixture, it will crack easily; if too little cement is used, the sand and gravel will not be cemented together well. Fourth, the concrete must be kept in the forms and be allowed to harden for days before it is used. Thus, in road-building traffic is not allowed on the road until weeks after the concrete is placed.

The correct amounts of the cement, sand, gravel, and stone vary with the different uses of the concrete. For making sidewalks, roadbeds, and foundations, the mixture may consist of one part cement, two to three parts sand, and four to six parts

Ewing Galloway

Fig. 285. Building a Concrete Road

Cement, water, and crushed stone are placed in the big drum at the left. As it rotates, these materials are thoroughly mixed. The mixture then flows down the chute to the roadbed, where it is leveled by the workmen.

gravel or crushed stone (Figure 285). The top layer of sidewalks and roadbeds is usually made of cement and fine sand without the gravel or crushed stone. This makes it possible to give the surface a smooth finish.

Experiment 68: How can you make concrete?

Thoroughly mix one part of cement with four parts of sand. Add enough water, stirring the mixture to make a stiff paste. Transfer the mixture to a small box and allow it to stand. Moisten it thoroughly every day and after several days try to break it.

Place one box of the mixture under water and see if it hardens.

Exercise 11. Make a brief topical outline which you can use for a recitation on "Cement and Concrete."

Exercise 12. If concrete is being employed for building purposes in your neighborhood, observe the various processes which the workmen use and explain how and why they carry out each step.

Exercise 13. People often speak of "cement" sidewalks. Is this correct? Explain.

PROBLEM 5: HOW IS LIME USED FOR BUILDING PURPOSES?

Lime is made from limestone. You recall that limestone is one of the important building stones. While it is used directly for building, it is also the source of *lime*, a substance which is very important for construction purposes.

Courtesy *Rock Products*

Fig. 286. Six Limekilns in a Row

The limestone is dumped into the top of the kiln from the platform shown at the top. See Figure 287 which shows the construction of a kiln. Each of these kilns can produce from 12 to 15 tons of lime a day.

Experiment 69: How can you make lime?

Break a lump of limestone into small pieces and place them in a crucible or small iron dish. Heat the limestone to a red heat for an hour. Allow it to cool. Observe that the white substance which is left crumbles easily. When it is quite cool, add a few drops of water and note that the lime becomes warm. (If you have no way to heat the limestone, get a small lump of *quicklime* from the lumber-yard or some other place where lime is sold.)

Lime is the white material which you have probably seen where brick or stone walls were being built or where buildings were being plastered. The stone-mason or brick-layer adds water to lumps of lime in a mortar-box. The water often becomes so warm by its chemical action on the lime that some of the water is changed to steam and rises above the box.

Lime is manufactured in large quantities in a way similar to that used in Experiment 69. Limestone is placed in a cylindrical kiln (Figures 286 and 287) lined with fire-brick. The fire around the bottom of the kiln is started, and the hot gases rise through the limestone, which decomposes, giving off carbon dioxide which escapes with the fire gases. The limestone becomes porous as it decomposes, and some of it crumbles into powder. This lime, called quicklime, settles to the bottom of the kiln where it is removed, as shown in Figure 287.

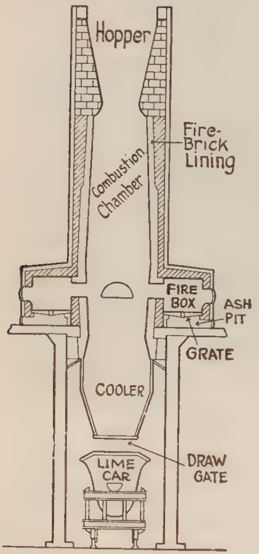


Fig. 287. Sectional View of a Limekiln

The hot gases from the fire-box pass upward and decompose the limestone. The lime sinks to the bottom, where it is dropped into the lime car when the draw gate is opened.

Lime is used to make mortar, plaster, and stucco. In very early times walls of brick and stone were laid without mortar, but even the Egyptians, Greeks, and Romans knew how to make and use mortar. *Mortar* and *plaster* are made in much the same way. Water is added to quicklime, with which it combines to form *slaked lime.* Then enough water is added to make a thin paste. Sand is mixed with this in proper amounts to make a stiff paste. Usually some cement is also added to give the mortar greater strength when it hardens. If it is desired to have colored mortar, coloring material is mixed in. For making plaster, hair or wood pulp is added to the mixture of sand and lime. These materials help to hold the plaster together. *Stucco* is a plaster or mortar used to finish the outside of buildings. The building is covered with wire netting or laths of wood or iron, and the stucco is then put on. The rough surface adds to the appearance and helps prevent cracks showing.

Experiment 70: How can you make mortar?

Add water to some lumps of quicklime. Note how the lime crumbles and that it becomes too hot to touch. Continue to add water slowly, and stir until you have a thin paste. Then add sand until a thick paste results. Place this paste in a small box or between two bricks, and allow it to harden. After several days or weeks place a few drops of an acid on the mortar and note the bubbles formed by the action of the acid. The mortar has in part changed to limestone.

When mortar, plaster, or stucco hardens or "sets," the slaked lime combines with the carbon dioxide of the air to form limestone. In time the limestone becomes very hard and securely holds the sand particles in it. If cement is used with the lime and sand, the cement sets by combining with the water present and forms a hard stone. You can show the presence of limestone in hardened plaster, mortar, or stucco, by adding a few drops of acid and observing the bubbles of the gas formed.

Exercise 14. State the differences in making lime, mortar, plaster, and concrete.

Exercise 15. Collect samples of hardened plaster, mortar, and stucco. Test them with an acid to see if they contain limestone.

PROBLEM 6: HOW IS GLASS MANUFACTURED?

The peculiar properties of glass make it usable for many purposes. When glass is hot and soft it may be molded, pressed, or blown into any shape, but when cold, it is very hard and durable and is not acted upon by air, water, and most chemicals. It breaks rather easily when struck a sharp blow, but can bear great weights without cracking. Sudden changes of temperature may crack it. When heated, it does not change to a liquid at a definite temperature like some solids (ice, for example), but gradually becomes soft and plastic as the temperature is increased. In cooling it slowly changes back into a solid, allowing time for molding and shaping it. Probably its most important property is its *transparency;* because of this property no good substitute for it has been found.

Glass is manufactured in large tanks lined with fire-brick and heated by flames of burning gas. The hot gases from the burners pass over the mixture of raw materials in the furnace and melt the ingredients together into a soft mass. When the mixture has thoroughly combined to form glass, it is ready to be blown, pressed, or rolled into shape. The mixture which is placed in the furnace to make common glass usually consists of sand, mixed with soda and limestone in about the following proportions: sand, 6 parts; soda, 2 parts; limestone, 1 part. Window glass and cheap plate-glass are made of such mixtures.

Keystone View Co.

Fig. 288. Blowing Glass

The man in the foreground is blowing a ball of glass to be drawn into a large cylinder. Back of this man you can see the hole into the white-hot furnace, from which the other man is drawing another ball of molten glass.

The different shapes of glass articles are produced by blowing, molding, and rolling. To make small tubes, the workman, called a glass-blower, dips one end of an iron tube, a few feet long, into the molten, or liquid, glass through a hole in the side of the furnace. He twists the tube and withdraws it, bringing out a small ball of glass on the end of the tube (Figure 288). By blowing in the other end he can form a small opening inside the ball, and then, by clamping one end of the glass ball in place by means of machinery and pulling on the iron tube, the hollow ball of glass can be drawn out into a long cylinder.

For making window glass a large ball of glass on the end of a blowing-tube is blown into a long cylinder a foot or more

in diameter. The cylinder is then split lengthwise with a diamond glass-cutter and laid in an oven. Here it softens and becomes flat. It must then be heated again and allowed to cool very slowly in another oven. This process is called *annealing*. Annealed glass does not easily break or crack. For rolling plate-glass the molten liquid is drawn from the furnace into a large metal pot and then poured on a large flat iron table. Here rollers squeeze it to the proper thickness. The plate when cool is uneven and must be ground and surfaced until it is flat and smooth. For making tumblers and bowls, and similar open vessels, the molten glass is poured into a mold of correct size for the outside of the vessel. A plunger which has the size and shape of the inside of the vessel is then pressed into the mold, squeezing the soft glass into shape. This process is called *pressing*.

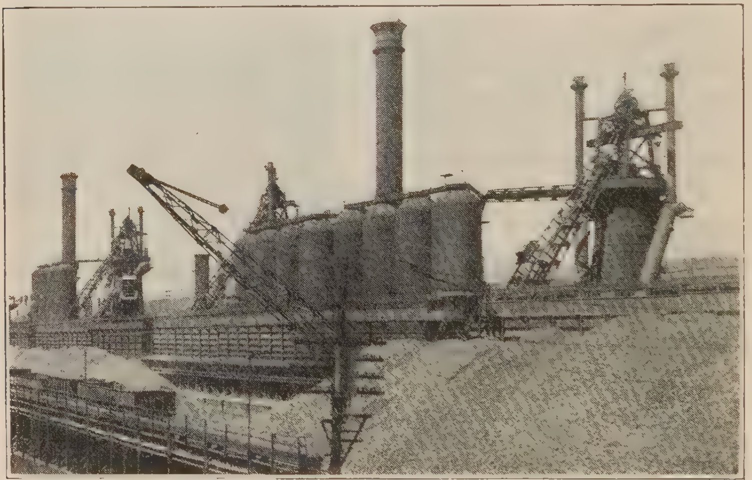
Exercise 16. Make a statement outline for a talk on "The Story of a Pane of Glass."

PROBLEM 7: HOW ARE METALS OBTAINED AND USED?

We live in the "metal age." The manufacture of iron and steel is the world's greatest industry. Such great industrial centers as Pittsburgh, Gary, and Birmingham owe their development to the huge iron and steel plants. Large city buildings, bridges, steam engines, automobiles, ships, and railroads are but a few of the important constructions for which iron and other metals are used. Fences, nails, bolts, stoves, furnaces, sewers, tools, tableware, hardware, and thousands of other necessary articles are manufactured from metals like iron, copper, lead, zinc, and aluminum. Besides these more commonly used metals, there are many others, like manganese, mercury, arsenic, bismuth, cadmium, chromium, molybdenum, nickel, cobalt, silver, gold, platinum, tin, and tungsten. While a few of the metals are found free, or uncombined with other materials in the earth, for example, gold, platinum, and copper, the principal sources are rock-like ma-

terials, called *ores*, composed of compounds of the metals. It is from these ores that the metals are manufactured.

Iron must be freed from its ore. Let us consider how iron, the most important of all metals, is obtained from its ores. After the iron ore is taken from the mine, it is shipped to the iron or steel mills. Here it is put through a process called *smelting*. This is carried out in a blast furnace (Figure



Courtesy Colorado Fuel and Iron Company

Fig. 289. Blast Furnaces

One blast furnace is shown most clearly at the extreme right. You can see the small car on its way to the top of the furnace. It is filled with iron ore obtained from the huge pile of ore in the foreground. To the left of the blast furnace are large containers which heat the air before it enters the bottom of the furnace. Examine also Figure 290.

289), which is a large steel tube lined with fire-brick. The ore is mixed with coke and limestone in proper amounts, as determined by the kind and quality of the ore used. This mixture is dropped into the furnace as shown in Figure 289.

Hot air enters the furnace near the bottom and keeps the coke burning in the lower part of the furnace. As the coke burns, the limestone is heated and changes to lime and carbon

dioxide. (See page 304.) The lime left from the decomposed limestone combines with the melted rock-like impurities in the ore to form a liquid called *slag*. At the same time the iron is freed from the ore. It is melted by the great heat, and, being heavier than the slag, sinks to the bottom of the furnace. Through the openings at the side (Figure 290) the slag and iron are drawn off from time to time. The slag becomes hard when cool and is used to manufacture cement and fertilizers. The iron is drawn off into molds, where it hardens and forms *pig iron*. Pig iron contains many impurities which must be removed before it can be used for making steel. If you are interested to know how steel and malleable iron are made, how tools are made of steel, and other interesting things about iron and steel, read about them in the references for Unit X or in a chemistry textbook.

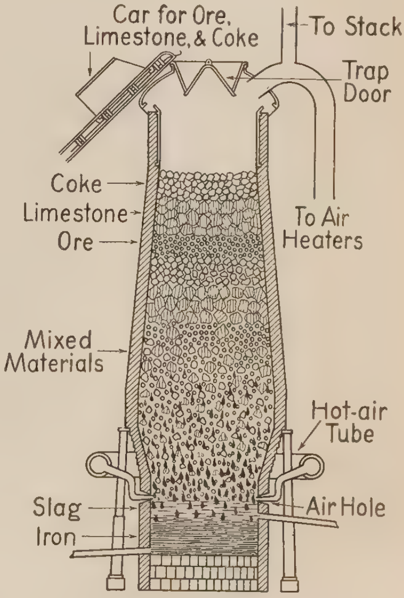


Fig. 290. Sectional View of a Blast Furnace

The gases which come from the top of the furnace go to the heaters, where they heat the air before it enters the furnace. The black drops at the lower part of this picture are melted iron freed from the ore.

Exercise 17. Explain why each of the following substances is used in producing pig iron: (*a*) iron ore, (*b*) limestone, (*c*) coke, (*d*) hot air.

Other metals are obtained in various ways. The processes used to separate other metals from their ores depend upon the

kind of compound in which the metals are found in the earth. For example, lead, copper, zinc, and mercury are found in combination with sulphur. To get any one of these metals from its ore, it is necessary to roast or heat the ore in the presence of oxygen. The oxygen burns away all or a part of the sulphur and combines with the metal, forming an *oxide* of the metal. The oxide can then be heated with coke or some other material which will remove the oxygen and leave the metal free. Other metals, like silver and aluminum, are separated from their ores by the use of electricity.

Exercise 18. Make a list of the ten to fifteen most common metals. Under each write several uses. Following each use indicate the properties of the metal which give it the use.

This unit has given you some knowledge of the many materials in use for making different things. It will suggest many more not discussed here, but which you see or handle every day, such as rubber, leather, celluloid, paper, graphite (used in our pencils), etc. These will be interesting topics for you to investigate.

Review Exercise on Unit X. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit X and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT X

1. Examine hardwood logs or stumps and find, by counting the annual rings, the age of the tree which was cut.

2. Add to your list (Exercise 2, page 289) as many more advantages and disadvantages of wood as you can.

3. Make a collection of small pieces of different kinds of wood and label each.

4. Visit any industry where building materials are being made, and write a report of the important steps in the preparation of the finished product.

5. Write to the manufacturer of the chinaware you use at home, requesting any pamphlet, chart, or booklet which describes or shows how the dishes are made. Summarize the principal steps.

6. Observe men at work building sidewalks, or foundations and walls of a building, and see what they use. Explain why each material is used.

7. Make a list of the uses of glass. Collect samples of different kinds of glass and label them.

8. What chemical changes have been mentioned in Unit X? Check through the unit and summarize them.

9. Why are concrete sidewalks and roads laid with space between the sections?

10. Why is a space left between the ends of two railroad rails? Between the end of an iron or concrete bridge and its support?

11. The relative hardness of stones is determined by rubbing the stones together. The harder stone scratches the softer one; the softer one leaves a deposit on the harder one. Test as many kinds of stone as you can find and list them in order of hardness.

12. City newspapers often have a section on the construction of new buildings. Turn to this section and read about the materials used. Also, write to some of the companies which furnish such materials, and obtain their pamphlets. From these you can prepare interesting reports to be given in class.

UNIT XI

MACHINES FOR DOING WORK

Preliminary Exercises

1. Make a list of the "labor-saving devices" which are used in the home; on the farm; in the factory. Use only the left half of the page.

2. Opposite each labor-saving device listed in Exercise 1, indicate the method of doing the work before the device was invented.

3. What are some machines used today which may likely be replaced by new inventions?

4. Name the machines which you think have contributed most to man's progress.

5. Why are wheels placed on wheelbarrows?

6. Why are rollers placed under large buildings in moving them?

7. List the principal sources of "power" used to do work.

8. Which do you think is more work: (*a*) carrying 100 pounds up a stair 50 feet high, or (*b*) carrying 20 pounds up a stair 250 feet high? Why?

9. Why does a man roll a barrel up a plank into a wagon instead of lifting it into the wagon?

THE STORY OF UNIT XI

In Unit X the present age was called "the metal age," but it might just as well be called "the age of machinery," for there is little work which man does today without the use of some device or *machine*. Few machines now used were known before the nineteenth century. As new materials for construction, such as the metals, were discovered, many new machines could be made. The number and variety have become so great that we depend upon them every hour of the day.

Everywhere, in homes, on the streets, in the fields, and in the offices and factories, man saves his strength and time through the use of simple devices. He has learned to make use

of his own physical strength and of the strength or force of animals, wind, water, steam, and electricity, by inventing devices which help him to do his work more efficiently. The bones, sharp stones, or crude wooden instruments which he used as plows have been replaced by steel plows drawn by horses and tractors (Figures 291 and 292); the scythe can no longer compete with mowing machines and reapers; the primitive method of grinding grain has been nearly forgotten since the development of flour mills and feed grinders; horse-drawn vehicles have yielded to the steam engine, the automobile, and the electric car; hand, or manual, work in the kitchen, field, and factory is to a considerable extent now done by "labor-saving" machines of many different kinds.

Keystone View Co.

Fig. 291. Primitive Plowing

The water buffalo is drawing the plow made entirely of wood. Compare this with the method shown in Figure 292.

"There is work to be done" is an expression which you hear constantly. If you examine into the nature of work, you find that it may be mental, that is, work of the mind, or it may be manual, that is, work that requires the use of your physical strength or the use of some other force to push, pull, or lift some material. Though we use machines of different varieties to aid us in both kinds of work mentioned, we shall consider here only physical work and the devices used by man to do such physical work.

To the scientist the term *work* means exerting a force through a distance; that is, the force must move something, or no work is done. This force may be your own physical

strength or some force which you can make use of to save your strength and your time. If by pulling, pushing, or lifting, you succeed in moving an object, you do work. You would not, however, do work in lifting, pulling, or pushing on a house, an automobile, or other large object which you could not move. You would not, in these cases, accomplish anything; that is, you would not move the object through a certain distance. This gives you a new meaning of the word work.

Courtesy International Harvester Co.

Fig. 292. A Modern Plow

The gasoline tractor turns three wide furrows at one time. One man can plow 11 to 13 acres a day with such a machine. Compare this figure with Figure 291.

The amount of work which you do depends upon the force which is used and the distance through which the force is exerted. For example, if you lift a 50-pound sack of sugar from the floor to a table 3 feet high, you do more work than when you lift a 25-pound sack of sugar the same height, or when you lift a 50-pound sack to a stand one foot high. As another example, a man weighing 250 pounds does more work in climbing stairs 50 feet high than in climbing stairs only 10 feet high. Similarly, more work is done by the man in climbing 50 feet than by a 75-pound boy who climbs the same height. And so

Fig. 293. An Inclined Plane

Such arrangement is a machine. The man cannot lift the barrel of salt into the wagon, for it weighs 300 pounds. To roll it up the plank requires a force of only 150 pounds.

you see that the force used and the distance through which the force acts determine the amount of work done.

You might think that the speed with which you move an object determines how much work is done. This is not true. Whether the 250-pound man runs up the stairs or walks up slowly makes no difference in the amount of work done. It may make him more tired to run up the stairs, but he accomplishes exactly the same work in either case: he lifts 250 pounds to a height of 50 feet. The *rate of doing work* does not determine the *amount of work done.*

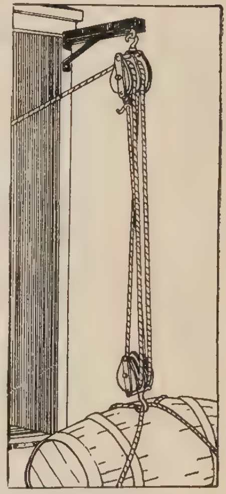


Fig. 294.
A Block and Tackle
With this machine a man has to pull with a force of less than 100 pounds to raise the 300-pound barrel.

It is to do work, that is, to exert a force through a distance in order to move an object, that machines are used. These devices help you in various ways. Besides saving your strength and time, machines have three advantages: First, they allow you to use a small force to move a heavy object. For example, to place a heavy barrel in a wagon, you may roll the barrel up a plank (Figure 293). Though you could not lift the barrel into the wagon, you can exert enough force to roll it along the plank. Or, you may use a block and tackle (Figure 294), and by means of a small force lift the heavy barrel. Second, some machines allow you to use a large force to move a light object through a greater distance than the force is moved (Figure 295).

Fig. 295. A Simple Machine
By moving the left hand upward a small distance the snow on the shovel is lifted a greater distance. This is a lever.

Third, machines allow you to exert a force in one direction and move an object in another direction. For example, with a crowbar or pry-pole you can push downward on one end to move a weight upward with the other end. (See Figure 310, page 328.) Or you can, by a pulley arrangement (Figure 296) pull in any one of several different directions to move the box upward.

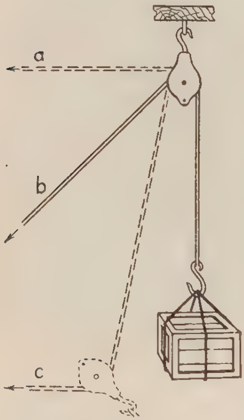


Fig. 296. A Pulley Used as a Machine

To move the box upward the rope may be pulled in direction (*a*) or direction (*b*); or if another pulley is used, the rope may pass through it and be pulled in direction (*c*).

The forces used to operate these machines are many. In early times man used his own strength. Later, the strength of oxen and horses was of great assistance to him. Still later, as he discovered simple machines of different kinds, wind and water were harnessed to run his windmills and water wheels. In modern times steam, electricity, and the explosive force of gas provide forces which have completely changed his way of doing work. Factories do much of the work that was done in the home, because one man with a good machine can do many times as much work as one man can do by hand. Through learning to make use of the forces of nature with the aid of machines, man has been able to advance to his present state of efficiency.

PROBLEM 1: WHAT IS A MACHINE?

Let us now get a clear idea of what a machine is and of the different kinds that are commonly used. Ordinarily you think of a machine as a complicated sort of thing like an automobile, a sewing machine, a reaper, or a washing machine. These are machines, but they are combinations of several different kinds of simple machines. Let us see what a simple machine is and how it works.

There are several types of simple machines. The most commonly used machines are found in your body. When you walk or run, sit down or get up, or lift, push, or pull an object, you do work by using the machines in the body. Like the sewing machine or locomotive, the human body contains many simple machines. Figure 297 shows, for example, one of the simple machines of the body. The muscle contracts and pulls up on the fore-arm, while the elbow does not move. The result is that the hand and the weight are lifted. Such a simple machine is called a *lever*. Various arrangements of the lever are used, as shown in Figure 314, page 331.

Fig. 297. A Lever

The elbow acts like a hinge; the muscle shortens and pulls the hand upward.

A second type of simple machine is that shown in Figure 298. Here, by turning the handle or wheel around as shown by the broken line, the heavy weight is slowly moved upward as the rope wraps around the axle. Only a small force is necessary to move the handle, but a weight many times as great as the force (measured in pounds) is lifted. Any machine like this is called a *wheel and axle*. It might just as well be called a crank and axle. Figure 320, page 334, shows several forms of this type.

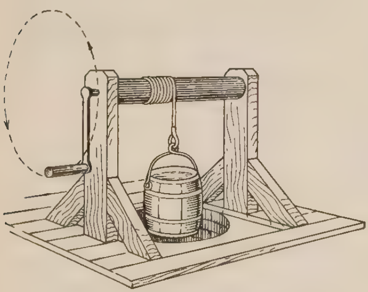


Fig. 298. A Wheel and Axle

A large wheel could be used instead of a crank. The rope is wrapped on an axle attached to the wheel. Do you now see why this is called a wheel and axle?

A third example of a simple machine is seen in the plank with which a man is able to raise a heavy barrel into a wagon (Figure 293). Without the plank the man could not lift the barrel. With the machine he is able to roll the heavy

object up the plank and place it in the wagon. The force in pounds necessary to push it along the inclined plank is far less than the weight of the barrel. This kind of machine is called an *inclined plane*. *Screws* of all kinds, such as the jack-screw shown in Figure 299, belong to this class of machines. By turning the handle of the jack-screw, a weight resting on top of the screw can be moved upward. Only a small force is needed to turn the handle, even if the weight lifted is a large one. The inset in Figure 299, which illustrates a triangular piece of paper wrapped around a rod or pencil, makes it clear that the screw is nothing more than a circular inclined plane. Similarly, the grade of a road winding up a mountain is an inclined plane which allows heavy loads to be raised to higher levels by the use of a small force. (See Figure 353, page 364.)

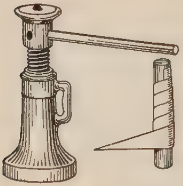


Fig. 299. A Jack-Screw

As the handle turns away from you, the screw moves upward.

A fourth kind of simple machine is the *pulley*. Figure 300 shows two different uses of pulleys. The arrangement at the left makes it possible for the man to pull in one direction and move the weight in the opposite direction. The force necessary, however, is a little greater than the weight, because of the friction of the pulley. The arrangement at the right requires only about one-half as much force as the weight lifted, but the force must move twice as far. Why?

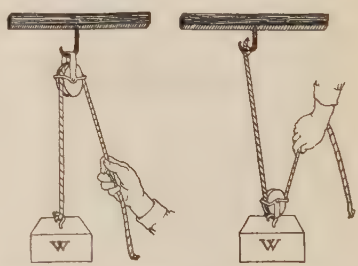


Fig. 300. A Fixed and a Movable Pulley

How far will the weight at the left be lifted if the hand moves downward one foot? How far will the weight at the right be lifted if the hand moves upward one foot?

A fifth very common simple machine is the *wedge* (Figure 301). Axes, picks, knives, plows, chisels, your front teeth, saws, and wedges for splitting wood are but a few examples.

All of these are used to overcome the force which holds different materials together. By means of a wedge it is possible for a small force to overcome a very great resistance. The force must, however, be exerted through a greater distance than that through which the resistance is moved. Thus, in Figure 301 suppose that the wedge is 2 inches thick at the top and 12 inches long. In order to spread the wood of the log

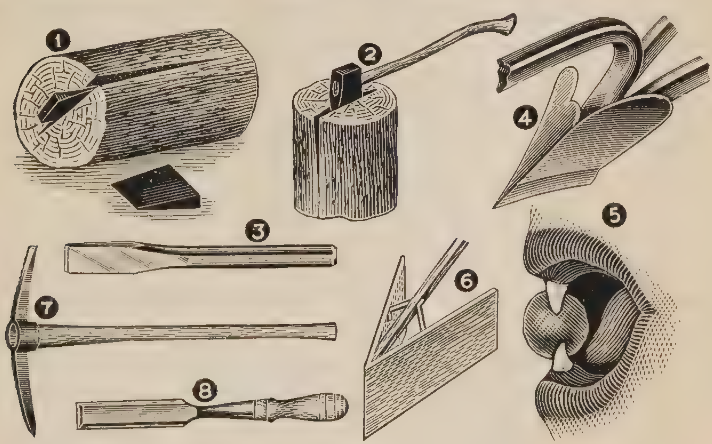


Fig. 301. Wedges in Daily Use
Try to name the eight machines shown in this figure.

2 inches, the force must be exerted through a distance of 12 inches, or six times as far as the wood is separated. Thus you see that a small force on the wedge can overcome the great resistance of the wood.

A sixth type of machine, which seems to be much different from those mentioned above, makes use of centrifugal force. Thus the stone in a sling has great force when the sling is whirled rapidly. The cream separator, for example, is a machine which makes use of this force caused by turning the crank. Water is pumped by centrifugal pumps in a similar way. Such machines are called *centrifugal machines.* A machine of this kind is shown in Figure 339, page 353.

Machines do not save work. You can see from the few examples mentioned that many simple machines are used to do work in the home, in the factory, and on the farm. They do not, however, as one commonly hears, "save work." The amount of work needed to make a machine operate is, because of friction, always greater than the work which the machine does. Why, then, are they used? The answer to this question will explain what a machine is, and may be stated as follows: *A machine is a device which uses energy to do work more effectively than it can be done without such device.*

The force which is used to operate a machine may be human or animal strength, or the energy of air, water, steam, electricity, light, or heat. In all cases the energy used on the machine must cause the machine to move some object by lifting, pulling, or pushing it, that is, by overcoming the resistance which tends to keep it from moving. The resistance may be due to the weight of the object caused by the attraction of the earth, or gravity, to *friction* between the object and the material on which the object rests, or to the force which holds parts of the same material together. Thus, when you use a machine to lift an object, that is, move it to a higher level, the work done results in raising the object against the pull of gravity; when you pull or push an object by the use of a machine, you must put force of some kind into the machine so that the machine will overcome the friction between the object and the material on which it moves; when you use a machine to separate materials, as in the case of a wedge used to split wood or of a hammer used to pull a nail, you must exert a force on the machine, and the machine will then overcome the resistance of the materials to be separated. A machine does not save work.

Exercise 1. From your study of the paragraphs above and from your own experiences with different kinds of machines make a list of the various machines which you know, grouping them under the following heads: (*a*) lever, (*b*) pulley, (*c*) inclined planes, (*d*) wheels and axles, or cranks, (*e*) wedges, (*f*) centrifugal machines.

Exercise 2. The principal reasons for using machines are given below. Copy these, and under each, name several common machines which illustrate each use. Give, following the name of the machine, a particular everyday use, as shown in the example under reason 1.

(1) To move an object or overcome a resistance by using a force in a direction different from the direction in which the object is to be moved:

Example: Crowbar (lever)—to raise a stone by pushing downward on the opposite end of the crowbar.

(2) To lift a large weight by the use of a small force:

(3) To overcome a great resistance by use of a smaller force:

(4) To move a small weight through a great distance by using a large force through a small distance:

(5) To move an object more rapidly than the speed of the force which is used to operate the machine.

PROBLEM 2: HOW CAN YOU MEASURE WORK?

Every machine is used to do work. If, therefore, you wish to know how much work is done, you must have some way of measuring it. Just as you use the inch, foot, yard, or mile as a unit to measure distance or length, so you must have a unit for the measurement of work.

Work may be measured in different units. You know that the amount of work done by a machine depends upon the force exerted and the distance through which the object is moved. Work, you see, includes two factors: force and distance. The *unit of work* must, therefore, be a combination of a unit of force and a unit of distance.

Now there are two different systems of measuring force and distance. The *English system,* which is commonly used in our country and in Great Britain, measures force in ounces, pounds, or tons, and distance in inches, feet, yards, rods, or miles. The *metric system,* used in most countries and by scientists in all countries, measures force in *grams* or *kilograms* and distance in *millimeters, centimeters, meters,* or *kilometers.* The metric system is the simpler of the two. It is often called the decimal system, because each unit is multiplied by ten

Table XII. English and Metric Equivalents

UNITS OF FORCE (OR WEIGHT)	UNITS OF DISTANCE (OR LENGTH)
(A) English to Metric	
1 ounce (oz.) = 28.35 grams (g)	1 inch (in.) = 2.54 centimeters (cm) or 25.4 millimeters (mm)
1 pound (lb.) = 453.6 grams (g)	1 foot (ft.) = 30.48 centimeters (cm)
	1 mile (m) = 1.61 kilometers (km)
(B) Metric to English	
1 kilogram (kg) = 2.2 pounds (lbs.)	1 centimeter (cm) = .39 inch (in.)
1 metric ton (T) = 2204.6 pounds (lbs.)	1 meter (m) = 39.37 inches (in.)
	1 kilometer (km) = .62 mile (m)

to get the next larger unit. This makes the system an easy one in which to calculate. Table XII and Figures 302 and 303 show a few comparisons of the two systems. These will prove useful to you in calculation.

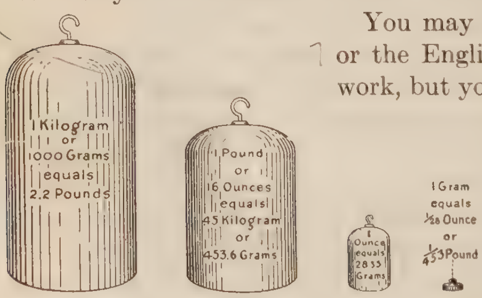


Fig. 302. English and Metric Weights
Compare these figures with those in Table XII.

You may use either the metric or the English system to measure work, but you must be careful not to measure force in one system and distance in the other. **Work equals force times distance.** The unit of work in the English system is the *foot-pound;* in the metric system it is the *centimeter-gram.* Thus, if you move or lift an object one foot with a pull or push of one pound, you do one foot-pound of work (Figure 304). Similarly, if you move or lift an object

through a distance of one centimeter with a pull or push of one gram, you do one centimeter-gram of work. If you lifted two pounds of material to a height of one foot, you would do

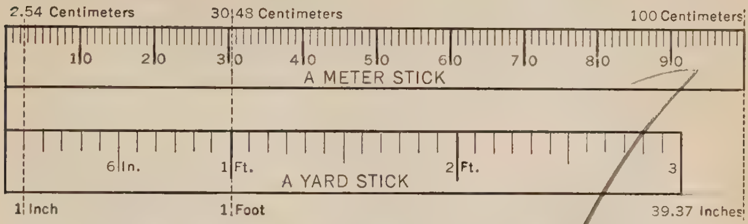


Fig. 303. English and Metric Units of Distance

How much longer is the meter than the yard? How many centimeters are there in one foot? Compare the figure with Table XII.

two foot-pounds of work. Lifting 10 pounds to a height of 5 feet would require 50 foot-pounds of work, or pulling on a sled with a force of 20 pounds for 100 feet would require 2000 foot-pounds of work.

Exercise 3. How many foot-pounds of work are done when you climb a stair 50 feet high?

Exercise 4. How many centimeter-grams of work are done when a weight of 2500 grams is lifted one meter?

Exercise 5. A winding road 1200 feet long leads up a hill 100 feet high. A horse pulls a load of coal weighing one ton to the top of the hill. To do this the horse must exert a constant pull of 200 pounds. (*a*) How much work does the horse do in pulling the load? (*b*) How much work is really accomplished by raising a load of one ton 100 feet? The difference between (*a*) and (*b*) is work used to overcome friction. How much is this?

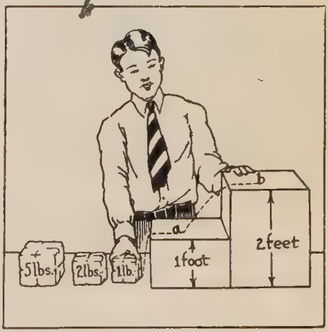


Fig. 304. Doing Work

How much work is done in lifting (*1*) the 1-pound bag up to (*a*)? To (*b*)? (*2*) The 2-pound bag up to (*a*)? To (*b*)? (*3*) The 5-pound bag up to (*b*)?

PROBLEM 3: HOW DO MACHINES WORK?

The number of different machines is so great that we shall consider only a few of the simpler types. Since the principle upon which all machines work is the same, let us see what this principle is by considering the inclined plane, the lever, the pulley, and the wheel and axle. If you understand these, you can explain any kind of simple machine.

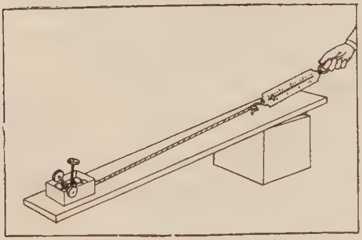


Fig. 305. Sliding Friction

The inclined plane shows the machine principle. Perhaps the inclined plane is more easily understood than any other machine.

Experiment 71: How does an inclined plane work?

(*a*) Get a smooth board a foot wide and eight feet long. Support one end of the board two feet above the table, allowing the other end to rest on the table. Provide also a small toy wagon or two sets of small wheels, a box, and some iron weights or stones. Place the weights or stones in the box and weigh the box and contents. Also weigh the wagon or wheels. Attach a string or cord to the box and place it at the lower end of the board. Put the wagon or wheels in the box. With a spring balance slowly pull the box and contents up the board (Figure 305). Read the balance while you are pulling the load. Record the total weight of the load which you obtained by weighing box, wheels, and weights, and also the force necessary to move the load up the inclined plane.

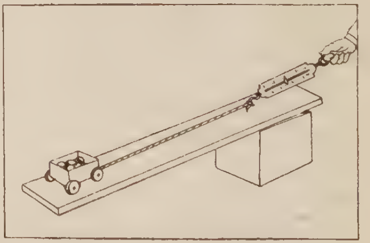


Fig. 306. Rolling Friction

(*b*) Now place the wheels or wagon under the box (Figure 306) and again pull the load up the plane, reading the balance. Record the force which is required.

Exercise 6. In both parts of Experiment 71 you see that the same weight or load was moved up the plane. What was the weight lifted? How high was it lifted? What force was required in part (*a*)? In part (*b*)? How much work was done by you in part (*a*)? How much useful work did the machine do? How much work did you do in part (*b*)? How much work did the machine do? What is the advantage of using such a machine? Write a report on the experiment, answering these questions as a part of your report.

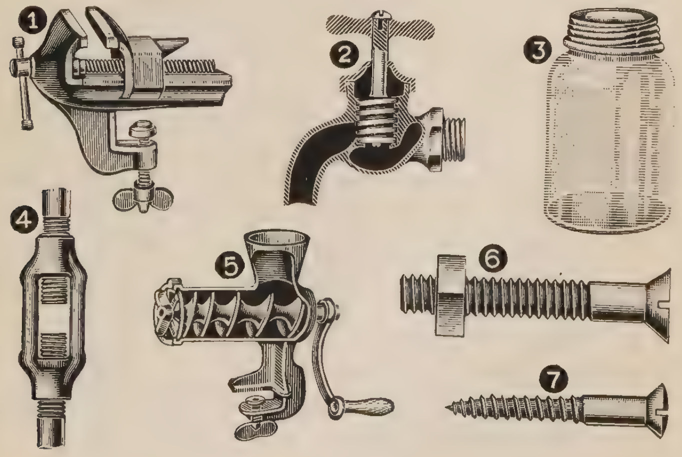


Fig. 307. Inclined Planes

Each of these machines is an inclined plane of the screw type. Compare these with the ones in Figure 299.

The inclined plane has a mechanical advantage. Experiment 71 shows that the inclined plane allows you to lift a heavy object with a small force, but that you must move the force through a greater distance than the weight is lifted. If there were no friction, it would require a force only one-fourth as great as the weight, for the distance through which the force acts is four times as great as the distance the weight is lifted. Such a machine would have a *mechanical advantage* of *four*, because the weight is four times as great as the force required to lift it.

The efficiency of machines varies. The work which you put into the machine in part (*a*) of Experiment 71 is much greater than the work which the machine does for you. You exerted a certain pull through a distance of 8 feet to lift a certain weight 2 feet. If you divide the *work out* (2 feet times the weight of the load) by the *work in* (8 feet times the pull necessary to draw the load) and express the quotient in per cent, you have the *percentage efficiency* of the machine used in part (*a*).

Exercise 7. What is the efficiency of the machine used in part (*a*) of Experiment 71?

Exercise 8. What is the efficiency of the machine used in part (*b*)?

No machine is one hundred per cent efficient. There is always some friction in every machine. The "work in" must be more than the "work out" because the "work in" must overcome the friction as well as move the object. If there were no friction in the machine, the weight times the distance which it is lifted would equal the force times the distance it moves. This is the principle of every machine. It is easy to remember as the scientist states it: F times d_f equals W times d_w. (d_f means the distance which the force moves; d_w means the distance which the weight is lifted.)

Exercise 9. Make a list of ways not mentioned in the text in which inclined planes can be used. (See Figure 307 for suggestions.)

Exercise 10. In order to get an automobile weighing 3200 pounds into a railroad car which is 4 feet above the ground, the automobile is pulled up two inclined planks 20 feet long. The force required is 1000 pounds. What is the "work in"? What is the "work out"? What is the efficiency? The actual mechanical advantage of the inclined plane is 3.2. If friction were neglected, it would be 5. Explain why these statements are true.

The lever is much like the inclined plane. A Greek scientist once said that if he had a pole long enough and strong enough and a place to rest it, he could lift the earth. He had just discovered how to use a lever. Since his time many different kinds of levers have been used.

Experiment 72: How does a lever work?

Balance a meterstick or a yardstick above a table by means of a string attached at the middle (Figure 308). Hang a large weight on the stick a few inches from the support. On the other side of the support, or *fulcrum*, hang a known weight, which is only about one-fifth as great as the large weight, at such point on the stick that the small weight just causes the balance to tip, lifting the larger weight. Bring the balance to a horizontal position and measure the distance of the weights above the table. Now allow the balance to tip until the small weight just touches the table. If the small weight is considered the force, how far did the force move? How far was the weight (the larger weight) lifted? What was the "work in"? The "work out"? What advantage has such a machine? What is the mechanical advantage of the machine? Shift the large weight to another position and repeat the entire experiment, answering the same questions for the second trial.

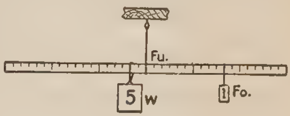


Fig. 308

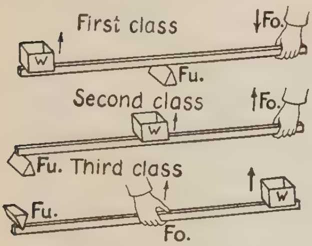


Fig. 309. Classes of Levers

In the third class lever the fulcrum end of the lever must be held down.

Exercise 11. Calculate the efficiency of the lever which you used in Experiment 72. Is this machine more or less efficient than the inclined plane used in Experiment 71? Why?

There are three kinds of levers. You can readily see that levers may be of three different kinds, as shown in Figure 309. The *first-class* lever has the fulcrum between the weight or resistance and the force; the *second-class* lever has the weight or resistance between the fulcrum and the force; the *third-class* lever has the force between the weight or resistance and the fulcrum.

In every lever of the first class the force is applied at one side of the fulcrum, and the object lifted or the resistance over-

come is on the opposite side. Many common devices belong to this class, such as the tack-puller, shears, pliers, pry-pole, teeter-totter, and boat oars. When the distance between the force and the fulcrum is greater than the distance between the weight or the resistance and the fulcrum, the mechanical advantage of the lever is more than one. This is true because the force is exerted through a greater distance than the weight or resistance is moved. Thus a long pry-pole (Figure 310) has a great mechanical advantage. When the weight and force are at the same distance from the fulcrum, the mechanical advantage is one, as in a balance (Figure 311). In cases where the force is closer to the weight or resistance, as in the case of boat oars, the mechanical advantage is less than one.

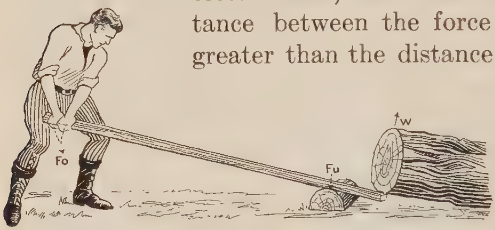


Fig. 310. A Pry-Pole—A First-Class Lever

A second man places a block under the log when it is lifted.

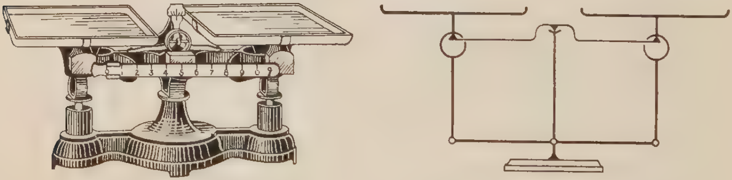


Fig. 311. A Lever of the First Class

The drawing at the right shows the lever resting on the support, and the pans at each end of the lever.

In second-class levers, such as the wheelbarrow and the post-puller, shown in Figure 312, the mechanical advantage is always more than one. The force always moves through a greater distance than the weight moves. The force is, therefore, always less than the weight or resistance, unless the friction happens to be very great.

Third-class levers always have a mechanical advantage of less than one. The force must always be greater than the weight or resistance, since it moves through a smaller distance. Still, third-class levers can be used to advantage. They make it possible for any object to be moved a greater distance than the force moves. Thus a crane (Figure 313) allows a force which moves slowly and through a distance of only a few feet to move an object rapidly through a great distance. Such machines have a *mechanical advantage of distance or speed.*

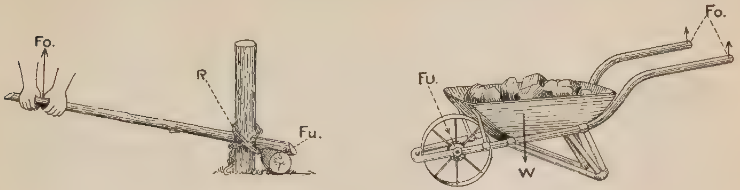
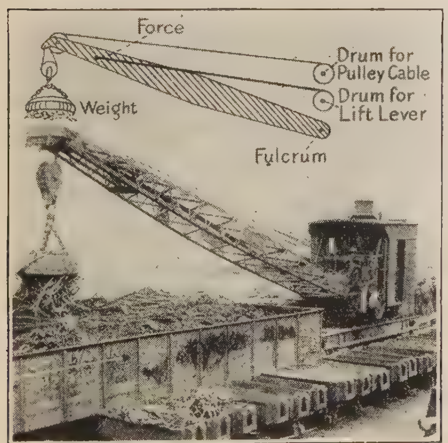


Fig. 312. Levers of the Second Class

The solid arrows, marked "Fo.," show the direction of the force.



Courtesy Brown Hoisting Machinery Co.

Fig. 313. A Lever of the Third Class

The force is exerted near the upper end of the crane, as shown in the inset above. Compare this with Fig. 309 (third class) so that you will understand how it works.

You see from your study of the lever and the inclined plane that the same principle applies to both kinds of machines. Weight times distance equals force times distance, when friction is neglected.

Exercise 12. A man has a pry-pole 10 feet long (Figure 310). He uses it as a first-class lever to lift a log, one end of which weighs 1000 pounds. The fulcrum is one foot from the end under the log. Explain how you determine what force he must exert to raise the log. Bear in mind that the log is lifted only one-ninth as far as the force is exerted, because the distance from the fulcrum to the force is nine times as great as the distance from the log to the fulcrum.

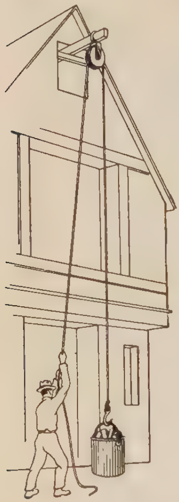


Fig. 314. A Single Fixed Pulley

Exercise 13. To which class does each of the levers in Figure 316 belong? Why? List each device, and opposite it state whether it is a lever of the first class, second class, or third class.

Pulleys are useful machines. You have seen combinations of pulleys used to lift objects, to pull boats out of the water, to operate cranes and derricks, and to move machinery. The simplest pulley is a fixed pulley (Figure 314). Its only advantage is to change the direction of the force, but even this is of great importance. You can, for example, lift an object to an upper story of a building by means of a pulley and a rope. You can use your weight to pull downward, moving the object upward. The force is practically equal to the weight, and one moves as far as the other. Why? If there were no friction, the force and the weight would be equal.

Experiment 73: How can different systems of pulleys be arranged?

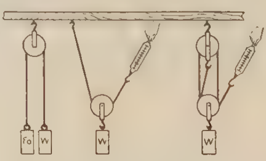


Fig. 315. Pulley Systems

(*a*) Set up a pulley as shown at the left in Figure 315, and hang an equal weight on each side. If you consider one weight the force and the other the weight or resistance, you see that they are equal and move the same distance. If you wish to move the weight, it is necessary to add more force to overcome the friction.

(*b*) Arrange a pulley as shown in the middle of Figure 315, using a spring balance. Weigh the weight and pulley. Now lift the weight

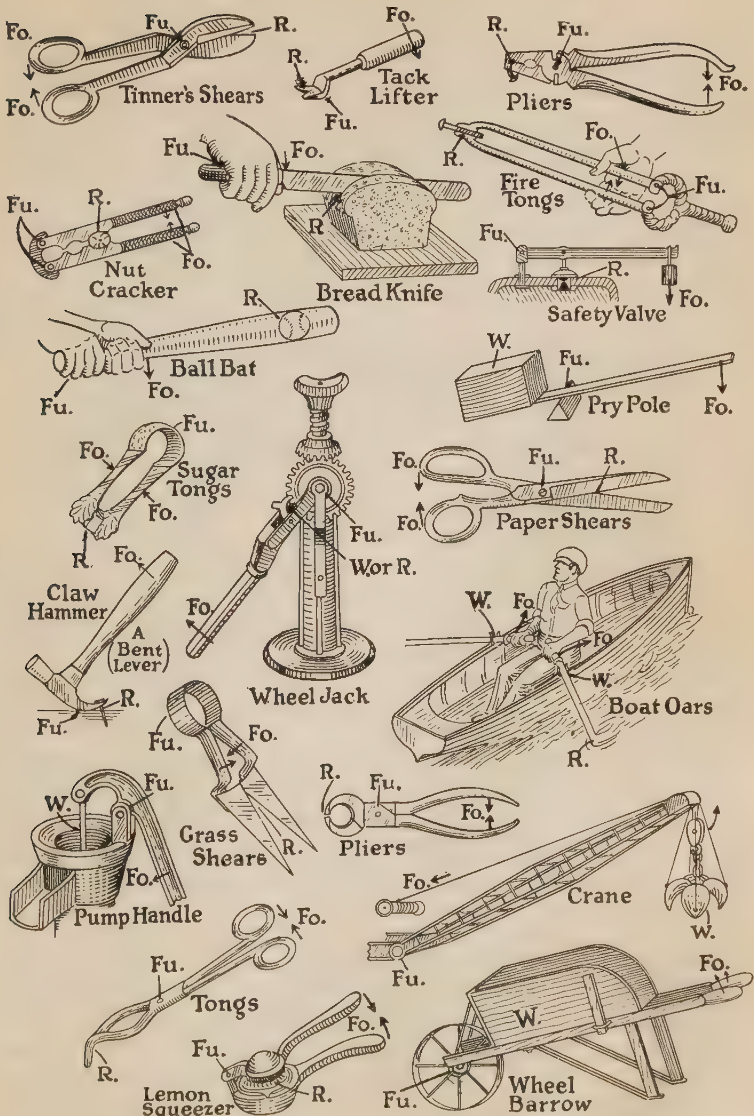


Fig. 316. Common Levers in Daily Use

and pulley by pulling upward on the balance, and read the balance as you move it upward. See how far the weight is lifted by moving the balance one foot. How does the relation of these distances compare with the number of strands of rope which support the pulley to which the weight is attached? What is the advantage of such an arrangement? Calculate the mechanical advantage and the efficiency of the machine.

(c) Set up a four-strand pulley system as shown at the right in Figure 315. This is commonly called a *block and tackle*. Experiment with this as you did with the two-strand system.

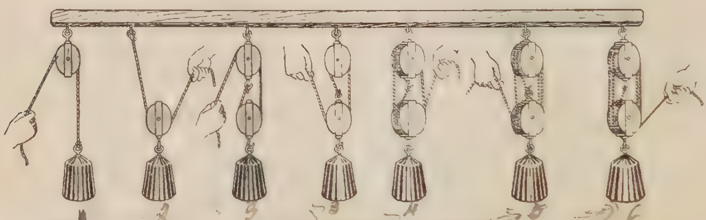


Fig. 317. Different Pulley Systems

In the systems which have two, four, and six strands supporting the movable pulley and the attached weight, is the tied end of the rope fastened to the movable or fixed pulley?

Exercise 14. Why is a single fixed pulley ever used if it has a mechanical advantage of only one?

Exercise 15. Draw the following systems of pulleys: 3-strand, 4-strand, 5-strand, 6-strand, 7-strand. (See Figure 317 for help.)

Exercise 16. The mechanical advantage of a set of pulleys is equal to the number of strands supporting the movable pulley, friction neglected. Why is this true? Give the mechanical advantage of each system shown in Figure 317.

The wheel and axle is very common. The wheel and axle is one of the oldest of the simple machines used by man. It finds a great variety of uses in the form of such machines as cranks of automobiles, coffee grinders, egg beaters, clothes wringers, and churns (Figure 320). The windlass (Figure 318) and the capstan (Figure 319) are wheels and axles used to pull heavy loads.

By examining Figure 319 you can see how the wheel and axle works. As the force moves the handle once around, the weight is moved by a distance equal to the circumference of the axle. Since the force moves much farther than the weight does, you see that a small force can move a large weight.

The circumference of a circle is $\frac{22}{7}$ times as great as its diameter. If the wheel has a diameter of 28 inches and the

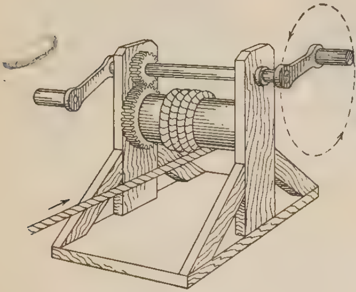


Fig. 318. A Double Wheel and a Single Axle

Two men can work this wheel and axle, called the windlass. The windlass must, of course, be securely staked down or bolted to keep it from moving.

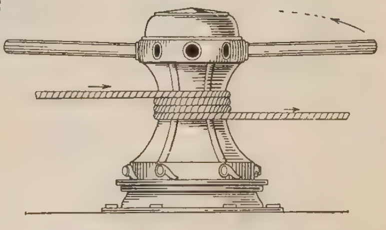


Fig. 319. A Capstan on Ship-Board

One man holds the rope at the right to keep it from slipping, other men turn the capstan by means of the bars, and the rope at the left (as it is wound on the axle) pulls in the heavy anchor. Explain the direction of the arrows.

axle has a diameter of 7 inches, how far does the force move in making one turn of the wheel? How far is the weight moved? How do these distances compare? Note that the comparison, or *ratio*, is the same as the ratio of the diameters of the wheel and the axle.

When the diameter of the wheel is greater than the diameter of the axle, the mechanical advantage of the machine is greater than one, and the force must move farther than the weight is lifted. Neglecting friction, the mechanical advantage can always be obtained by dividing the diameter of the wheel by the diameter of the axle, or by dividing the radius of the wheel or the length of the crank by the radius of the axle.

Another form of the wheel and axle is seen in a system of pulleys connected by belts, as shown in Figure 321. Such an arrangement is often used to transmit the force of one machine to another part of the machine or to a second machine. These pulleys are belt pulleys and are not like the ones previously

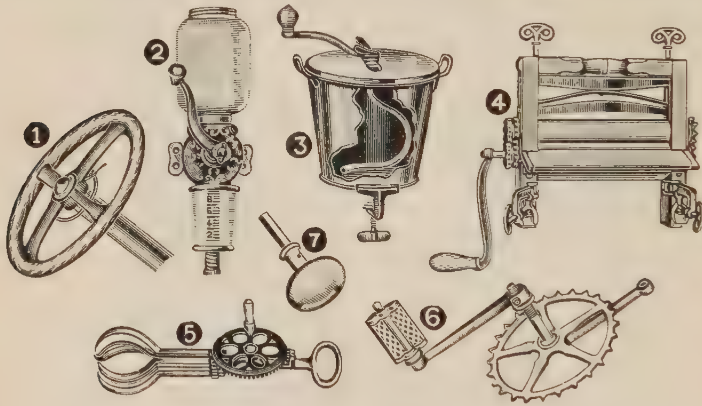


Fig. 320. Wheels and Axles in Daily Use

Name the seven wheel-and-axle machines shown in this figure.

described. The pulleys marked P, P′, and P″ are attached to engines and are known as the power pulleys. Those marked M, M′, and M″ are attached to machines which are to be operated by the engines.

If the pulleys are of the same size, they will turn at the same speed. The only advantage here is that the force can be transmitted to another machine some distance from the source of power. The belt may be twisted, of course, as in the middle drawing of Figure 321, in order to change the direction in which the second pulley runs. If the pulley on the engine is larger than the one attached to the machine, the machine pulley must make more revolutions than the engine, or power, pulley. Similarly, if the diameter of the engine pulley is only one-third the diameter of the machine pulley, the speed of the second pulley will be only one-third that of the first. By changing the sizes of the pulleys any desired speed of the

second pulley may be obtained. You see that this is really a wheel and axle used to govern the speed of a machine.

A very common form of the wheel and axle is the gear, which serves the same purpose as the belt pulleys just described. Years ago the force of a machine was transmitted to another part of the machine, or to another machine, by means of two smooth cylinders placed against each other. The friction between these caused the second one to turn when the first was revolved. Because they slipped easily, wasting power and making the speed of the second pulley or cylinder irregular, the cylinders were notched. Since these notches soon wore off, another improvement was made. Teeth were cut into the wheel or pulley, making what we now know as *gear wheels.*

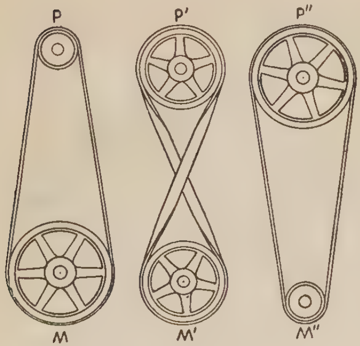


Fig. 321. Belt Pulleys

Each upper pulley is attached to the engine or power device; each lower pulley is attached to the machine to be operated. The belts transmit the power.

Gear wheels are used in a great many simple devices, as well as in most complex machines. If you examine Figure 318, you will find a small gear attached to the shaft of the wheel. This gear fits into a larger one on the axle. By such arrangement the force from the handles is transmitted to the axle. In the egg beater (Figure 320) and in the wheel jack (Figure 314), you find other simple machines which make use of gears to transmit the force. In more complex machines, like an automobile or a grain binder, many gears may be found.

Exercise 17. Examine various machines which have gears and answer the following questions: (*a*) Why are not machines made with a single gear wheel? (*b*) Why must the notches, or cogs, of two gear wheels like those in Figure 318 be of the same size?

Figure 322 shows how belt pulleys, gears, and gear chains may be used to transmit power. In the figure the large gear (A) is driving the small gear (B). Since there are four times as many cogs on the large wheel as on the small wheel, the small wheel will turn around four times while the large one goes

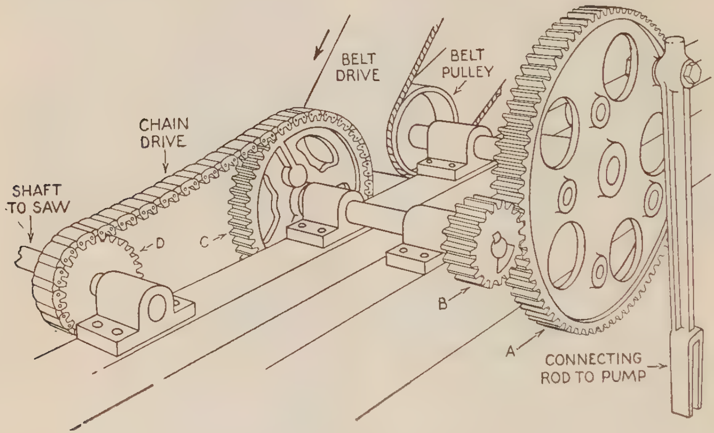


Fig. 322. Pulleys and Gears

This arrangement pumps water and saws wood. The belt drive comes from a large flywheel of a gas engine.

(*a*) Why does the pump rod move up and down as the belt pulley turns? (*b*) In which direction will the saw rotate? (Note the small arrow to the left of the belt drive and you can answer this question.) (*c*) How many revolutions will the saw make for one turn of the belt pulley? (Gear (A) is 4 times the diameter of gear (B), and gear (C) is 2 times the diameter of gear (D).)

around once. Since the teeth on two gear wheels which fit together must be of the same size, it is easy to see that the diameter of the wheels gives us the relative speed of the gears, and, therefore, the relative speed of the two parts of the machine to which the gears are attached. The common forms or types of the gears are the *spur gear*, the *bevel gear*, and the *worm gear* (Figure 323).

Exercise 18. Why are the pedals of bicycles placed at the end of cranks? What is the advantage of having two pedals?

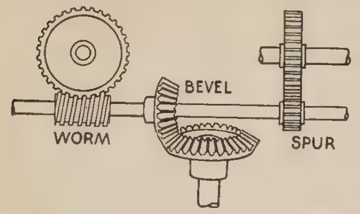


Fig. 323. Three Types of Gears

Suppose the power is applied to the shaft of the large spur-gear wheel. In which directions will the other gears be driven?

Exercise 19. In Figure 322 what is one advantage of having a large flywheel on the engine to which the belt is attached?

Exercise 20. If the crank of the windlass in Figure 298, page 317, is 15 inches long and the circumference of the axle is 15 inches, how far must the force be moved to lift the water 30 feet?

Exercise 21. Answer the questions under Figure 322.

PROBLEM 4: HOW CAN MACHINES BE MADE MORE EFFICIENT?

Machines do not save work. We use them because of other advantages, such as changing direction of a force, increasing the distance and speed at the expense of greater force, and increasing force at the expense of speed and distance. There is no machine which gives us something for nothing; there is no perpetual-motion machine; there is no possibility of getting as much out of a machine as we put into it.

Friction decreases efficiency. In the experiment with the inclined plane (page 324), you found that the wheels or wagon increased the efficiency of the machine. Let us see why.

Experiment 74: How can friction be reduced?

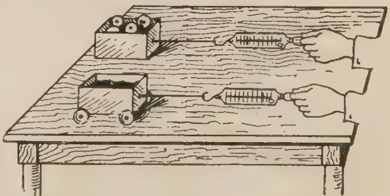


Fig. 324. Two Kinds of Friction

(*a*) In a chalk box or some other flat-bottomed container, place stone or iron weights and wheels, which will be used in part (*b*). Place the box on a table. Attach a string and spring balance to the box (Figure 324). Slowly pull the box along the table with the spring balance, and read the balance to see what

force is necessary to keep the box moving. Keep the balance parallel to the surface of the table.

(*b*) Place two sets of wheels under the box and again determine the force necessary to keep the arrangement moving. Results?

(*c*) Place the box containing the weights and wheels on small shot scattered on the table. What force is required to pull the box?

Exercise 22. Record your results. State your conclusions.

The forces required in parts (*b*) and (*c*) of Experiment 74 are far less than that required in part (*a*). In part (*a*) the box slides along the table. Neither the table nor the bottom of the box is entirely smooth; so the particles of both offer a resistance to the motion. The surface between table and box is very large; therefore the *sliding friction* is great.

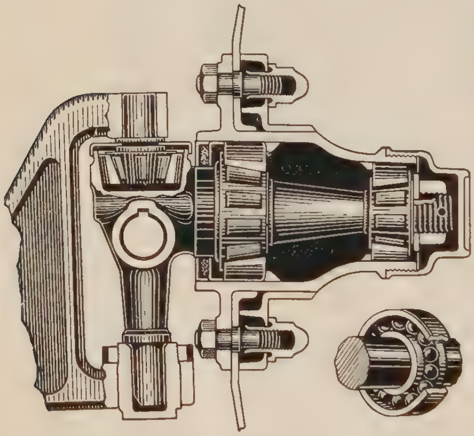


Fig. 325. Roller and Ball Bearings

The larger figure shows how roller bearings are arranged around the axle of the front wheel of an automobile to reduce friction. The small inset shows how ball bearings are used for the same purpose.

Friction can be reduced. You see that machines can be made more efficient by reducing the friction. A balance becomes more accurate—it is a more efficient machine—if the beam rests on a knife edge instead of on a large rough surface. The smaller the surface between two moving parts of any machine, or between one moving part and one stationary part, the less is the friction. Friction can be reduced by making the sliding friction as little as possible. Another way, as you have seen, is to substitute *rolling friction* for sliding friction. This can be done by using wheels and *ball bearings* or *roller bearings* (Figure 325). If these bearings are

kept well oiled, or *lubricated*, the machine becomes still more efficient.

You must keep in mind, however, that friction is very necessary. If there were no friction or too little friction between the engine wheels and the railroad track, for example, the engine could not move. The wheels would spin around without moving forward or backward. Or if there were no friction between your shoes and the floor, you could not move unless someone pushed you or you had a way of pulling yourself along. And if you once got started, you could not stop.

Exercise 23. What disadvantages of friction can you name? What advantages?

Exercise 24. Oiling a machine makes it more efficient. Explain why.

PROBLEM 5: WHAT IS THE SOURCE OF ALL FORCES USED WITH MACHINES?

All forces come from the sun. We have considered so many different forces that it does not seem possible that all of these can come from the same source. Yet every one of them can be traced back to the sun. It is the energy from the sun that gives us the force which we can exert with our muscles, the force exerted by animals in pulling and pushing, and the force of wind, water, steam, explosions, and electricity. These forces are all a part of the energy, or ability to do work, which the different materials possess. Let us see how these various forms of energy come from the sun.

Your muscular energy comes from the food you eat. As you expend some of your energy by exerting a force, you must, from time to time, take food. This food undergoes chemical changes and produces new compounds which build up new tissues in the body. These oxidize when you breathe and generate the heat of the body and the muscular energy to do work. (See page 85.) Now the food which you eat comes from plants, or from animals which feed on plants, and plants require sunshine to grow and to produce the food. (See page 80.) Without sunshine, then, you could not have energy, and could

do no work. The strength or energy of all animals can be traced to the sun in the same way.

It is very easy also to trace to the sun the force of falling or running water. The heat from the sun evaporates the water from the surface of the earth. As it is cooled and condensed by changes in weather, it falls as rain or snow. (See page 47.) The rain or melted snow then runs down streams. The running water possesses energy which may be used to run water wheels. It may fall over dams or water-falls and turn turbines.

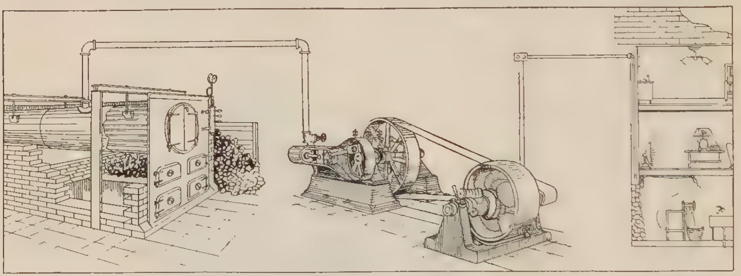


Fig. 326. Transformation of Energy

Can you trace the changes in energy from the coal pile under the boiler, to the steam engine, to the dynamo, to the lights, etc., in the house?

In either case it gets its energy from the sun, which caused the water to evaporate from lake, stream, or ocean, and to rise to higher levels.

Another source of energy, which we use in many machines, is steam. Steam is made by heating water. The water, let us say, is heated by wood or coal. As the wood or coal burns, the chemical energy of its elements is changed to heat. (See page 237.) But wood and coal both come from plants, which could grow only when the sun gave them the necessary energy to manufacture the compounds of which they are made. And so the energy of the sun makes it possible for us to have the force of steam to pull our trains and run machinery.

One kind of energy can be converted into another. The energy of the sun may change to chemical energy in the tree, the chemical energy changes to heat or light when the wood

burns (see page 237), the heat may produce steam, the steam may run a dynamo and produce electricity, the electricity may be changed to heat or light. This *transformation of one kind of energy to another* is certainly one of the wonders of nature (Figure 326). Energy can be changed to another form, but it can never be destroyed. There is always the same amount of energy in the world.

Exercise 25. Summarize Problem 4 and all cross references in the form of statements which tell how one form of energy may be changed into another, thus:

1. Radiant energy from the sun is changed to heat when it is absorbed by the earth.
2. Electric energy is changed to light in an electric-light bulb.

Review Exercise on Unit XI. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit XI and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT XI

1. Make up a practical problem for each kind of machine studied, and solve it, showing all of your work.

2. Opposite the machines in your list state the kind or kinds of simple machines in each.

3. List the kinds of simple machines which you can find in a sewing machine; in an automobile; in a meat grinder.

4. Explain how a scale like that shown in Figure 327 works. How were the distances between the notches on the left side of the lever determined?

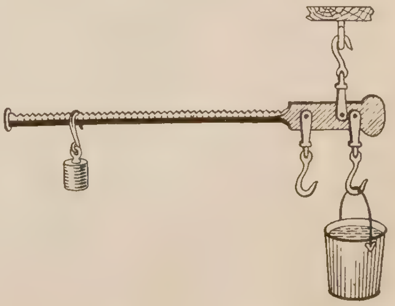


Fig. 327. A Steelyard

5. In pulling a heavy load up-hill a horse became so tired that he could go no farther. Was the horse working while he kept the wagon from rolling down hill? Explain your answer.

6. Can you explain how a claw-hammer works like a lever in pulling a nail?

7. In hauling stones on a wheelbarrow, where should you place the stones so that the handles may be lifted most easily?

8. Why do railroad cars have "hot-boxes"?

9. What is the difference in the kind of machine used to row a boat and that used to paddle a canoe?

10. Why are tinner's shears made with long handles and short blades while tailor's shears are made with short handles and long blades?

11. What different kinds of machines are used in your automobile jack?

12. Why is each of the following devices a machine: knife, wheelbarrow, ice-cream freezer, sugar tongs, nut cracker, vise, egg beater, saw, automobile crank, spade, hay fork, pliers, ax, chisel, pump handle, can opener, faucet, clothes wringer?

UNIT XII

PUTTING THE FORCES OF AIR AND WATER TO WORK

Preliminary Exercises

1. Name devices or machines operated by the force of air.
2. What are the characteristics of air which make it of use in the machines you listed in Exercise 1?
3. How can men work under water in constructing foundations?
4. How could you use a stream to run machinery?
5. At Keokuk, Iowa, and at Niagara Falls water is used to generate electricity. What determines the amount of electricity which can be generated? Why?
6. Of what use is compressed air to street cars and trains?
7. How do dams make possible the use of rivers for running machinery?
8. How can you empty a gasoline tank with the use of a rubber hose?
9. In what different ways does air pressure work for us?
10. How does a windmill pump water?
11. Explain the operation of a vacuum-cleaner.

THE STORY OF UNIT XII

As man discovered simple machines and learned to combine them into more complicated machines, he sought ways to save his own strength through the use of other forces which nature had provided for him. Among these forces, other than his strength and the strength of animals, are those of air and water. Man has found various ways of using the energy which these materials possess and has made many devices which put these forces to work. As a result we have today diving bells, sailboats, windmills, vacuum-cleaners, air and water pumps,

siphons, water wheels, turbines, air-brakes, hydraulic presses, hydraulic elevators, and a score of other labor-saving devices.

You recall that air occupies space, that it exerts pressure, and that it is compressible. These characteristics of air are made use of to do work. Air is forced into diving bells and caissons so that men can work under water (Figure 328). The pressure of air is useful in water pumps, self-filling fountain pens, medicine droppers, vacuum-cleaners, the siphon, and other devices (Figure 329). The compressibility of air and the outward force of compressed air serve us in inflating automobile tires, foot-balls, and basket-balls, and in the operation of such machines as water pumps, air-brakes, and compressed-air engines.

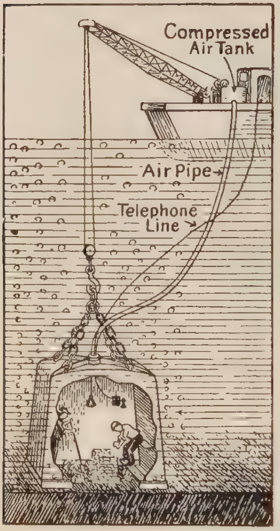


Fig. 328. Diving Bell

These men can work in safety far under water. Fresh air under pressure is supplied from the compressed-air tank.

Water, though not compressible, does exert a pressure because of its weight. The pressure therefore depends upon the depth of the water. Perhaps you know how great dams are built across streams to increase the depth and pressure. You may have observed how waterfalls can be used to drive machinery if the water strikes against a water wheel or turbine (Figures 345 and 330). It may fall upon a paddle wheel, or may be allowed to strike the paddles or vanes of a turbine. In either case the energy which the water has at the top of the falls may be utilized to do work.

Another way in which water is of help to us depends upon the facts that water is a non-compressible liquid and is free to move in all directions. For example, in a hydraulic press

pressure may be exerted on a piston in a small cylinder by means of a lever. This pressure forces water into a large tank

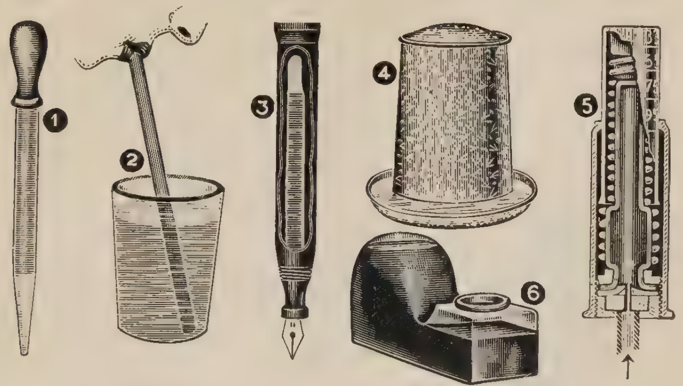


Fig. 329. Air-Pressure Devices

These simple practical devices all operate by air pressure. Number 4 is a watering device for chickens. Number 5 is a pressure gauge for automobile tires. What are the others?

into which is fitted a cylinder of greater diameter, thus pushing upward on the large cylinder. As you shall see later, the force upward on the piston of the large cylinder is many times greater than the force exerted on the small piston. This makes it possible to use water as a means by which force may be transferred from one place to another and be multiplied many times (Figure 351, page 362).

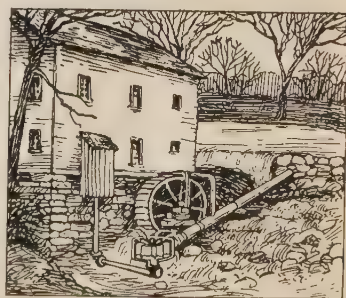


Fig. 330. A Water Turbine

Before the turbine was installed, the water wheel was used. You can see the pipe which formerly carried the water to the top of the wheel.

Since air and water have weight, they can exert a force when in motion. Moving air may run a windmill, which works for man by pumping water or by running other ma-

chines (Figure 331). Running water may turn a paddle wheel and thus help to grind grain, saw wood, or generate electricity. As the air strikes the vanes of a windmill, or running water strikes the vanes of a water wheel, the force exerted turns the wheel, and this force may be transmitted to other machinery by means of belts or gears. Great improvements have been made in the kind of machines used to harness the energy of moving air and water, but the force used is still the force of moving material. And it is interesting to know that man used the simple water wheel for nearly 2000 years before he discovered the modern methods of utilizing water power.

Fig. 331.
An Old-Time Windmill

This is the oldest windmill in America. It is in Massachusetts, and was built in 1746. Compare this windmill with the one shown in Figure 342.

It is easy to see that the amount of force of moving material depends upon the weight and speed of the material. As you learned in your study of weather, air has but a small weight. At a low speed it exerts a small force, but when it moves at a tremendous speed, as in a tornado, it may exert a force great enough to move a large building. Similarly in the case of water, you know that a stream which moves slowly can be waded very easily, but if the water is moving very rapidly, as in a mountain stream, the force is great enough to carry you off your feet. If the stream is large and moves rapidly, the force is tremendous. If you have been unfortunate enough to be in the path of a stream of water coming from a large fire hose, you need no words to help you realize the great force of such a stream. It is evident that the energy of moving air or moving water depends upon the weight and speed of the air or the water.

This brings you to a new idea or term of science, *power*, a word which you have often heard and have perhaps used incorrectly. It is common to speak of power when you really mean force. You recall that *force times distance equals work;* and that energy is the ability to do work. What meaning do scientists give to the term power? Power is not the same as force, work, or energy. Let us suppose that you climb a stair which is 50 feet high, your weight being 100 pounds. The force that is necessary to lift you is 100 pounds; the work that you do is 5000 foot-pounds; the energy used is 5000 foot-pounds.

Now you may take two minutes to climb the stairs, or you may require ten minutes. In either case you do the same work, but in the first case you do it five times as fast. The rate of work in the two cases is different. It is this rate of doing work which scientists call power. In climbing the stair in two minutes you do 5000 foot-pounds of work in two minutes, or 2500 foot-pounds per minute. In the second case you do 5000 foot-pounds in ten minutes, or 500 foot-pounds per minute. Your power in the first case is five times as great as in the second. Similarly, water or air may, depending upon their speed and weight, do work at different rates. We say that the *power depends upon the rate or speed with which the force is exerted*, and we measure the rate of doing work in a new unit, called *horse-power.* Later you will understand by what method scientists have come to determine this unit and how it is used.

You see, then, that air and water can save our strength; that air can be of use because it occupies space, exerts pressure, and is compressible; that the pressure of water may be utilized to do work; that the motion of air and water furnishes energy for man; that the speed of moving air and water determines the amount of energy which is available in a certain time, and that the rate of doing work, or the power of air and water, depends upon the force and the speed with which the force is exerted.

PROBLEM 1: HOW DOES AIR ENABLE MAN TO WORK UNDER WATER?

In using diving bells or caissons for constructing foundations under water, or in building underground tunnels, it is necessary to have air for the workmen. This means that the water must be kept out by means of air.

Air can be used to exclude water. You recall from Unit II that air is material. (See page 54.)

Experiment 75: How can air displace water from a container?

(*a*) Lower a tumbler, mouth downward, into a large vessel of water. Note that as the tumbler is forced down, the water rises into the tumbler but a small distance. How do you explain what you see? (See page 55.)

Fig. 332.
Displacing Water by Air

(*b*) Lower a large funnel fitted with a rubber tube into a jar of water (Figure 332). Does water fill the funnel? Why? Blow into the rubber tubing slowly and then withdraw your mouth. What happens during this process, and how do you explain it? Again blow until all air is forced out of the funnel, and then pinch the rubber tubing. Does water enter the funnel?

Exercise 1. Write an explanation for each part of Experiment 75.

When the diving bell, caisson, or tunnel is large and far under water, the pressure of the water is so great that it requires much force to keep the water out and to supply fresh air for the workmen. In order to force the air into the container where men work, compression pumps must be used. Figure 333 shows how such a pump works. As the piston moves to the right, Valve *B* opens and Valve *D* closes. The air is forced through Valve *B* through the discharge pipe which leads to the bell, caisson, or tunnel. Then as the piston moves back (to the left), Valve *B* closes, and Valve *D* opens, allowing more air to enter through the intake pipe which leads to the outside

air. Valve C now closes and Valve A opens. Thus the outside air is pumped into the container.

To provide against danger resulting from the breakdown of the pump, the air is forced into large compressed-air tanks which are connected to the caisson or tunnel. These tanks have heavy walls, and air may be forced into them until the pressure reaches from 1000 to 2000 pounds per square inch.

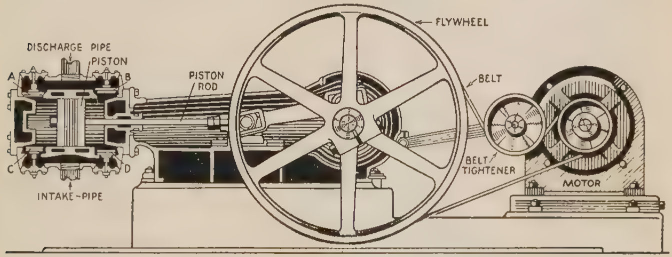


Fig. 333. An Air Compression Pump

The motor drives the flywheel which moves the piston rod and the attached piston back and forth.

Should the pump cease to work for a time, there is no danger for the workmen, because the pressure in the tank will supply air until the pump is repaired or until the workmen can come out. Speaking tubes, electric bells, or telephones connect the workmen with the outside world.

How men get into the diving bell or caisson. You have perhaps wondered how the workmen get into the bell, the caisson, or the tunnel. In the case of the bell, men enter before it is lowered into the water, and while it is being lowered, stay on the ledge built around the inside of the bell some distance above the bottom. The caisson and the tunnel are not so simple as the diving bell. In each of these are several compartments with air-tight doors between them (Figure 334). Air is forced into each compartment until all water is driven out. The doors between the compartments are then closed. Then men enter the first compartment and close the outside door.

Air is admitted slowly until the pressure in the first compartment is equal to that in the other parts of the tunnel or caisson. This requires some time, because a rapid change of the air pressure will injure the workmen. The door to the second compartment is now opened, and the men go in, closing the door behind them. This compartment may be the workshop. Fresh air is constantly supplied.

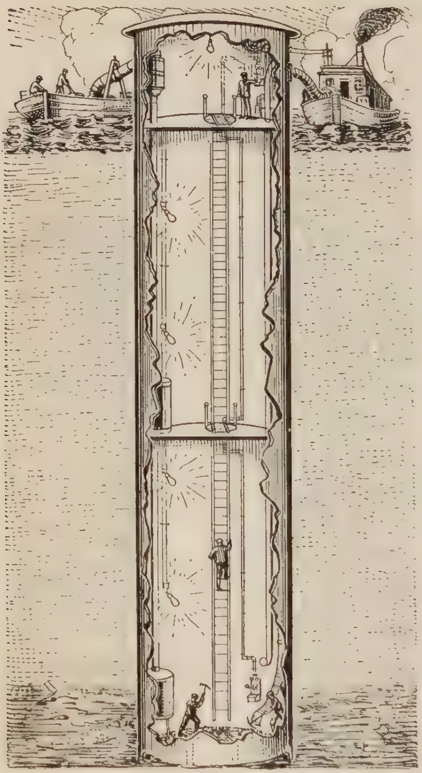


Fig. 334. A Caisson

The men are busy removing the packed dirt at the bottom. The dirt is carried up to the boat at the left.

As the men come out, they return to the first compartment and securely close the trap-door behind them. The air pressure is now very slowly reduced by allowing air to escape. When the pressure is the same as that outside, they may safely come out. You see that the caisson is really an under-ground or under-water tunnel in a vertical position.

Even with the many precautions such work is always dangerous on account of sudden leaks in the container or tunnel. The great changes in pressure to which the men are subjected are also a heavy strain on their health.

Exercise 2. Write a short report on "How Working under Water Is Made Safe by the Use of Air."

PROBLEM 2: HOW DOES ORDINARY AIR PRESSURE WORK FOR US?

In addition to water pumps, which you studied in Unit IV, there are two other devices commonly used in the home which depend upon ordinary air pressure for their operation. The first is the *siphon*, used to transfer liquids from one place to another, and the second is the *vacuum-cleaner*.

How the siphon works. Did you ever use a rubber hose to get vinegar from a barrel, to take the water from a fish bowl, or to get gasoline from a tank?

Experiment 76: How can you operate a siphon?

Get a piece of rubber tubing several feet long. (A piece of garden hose may be used.) Lower one end of the tubing into a pail of water which stands on a table. Suck the air from the tubing until the water reaches your mouth. Why does the water fill the tubing? (See Experiment 9, page 55.) Pinch the end of the tubing air-tight, or place your finger over the end of the tubing without allowing air to enter, and bring this end into an empty pail on the floor. Open the end of the tube and observe that the water flows from it. Slowly raise the open end until it is almost at the level of the water in the pail on the table. How does the speed of flow change? Again lower the open end slowly. Does the rate of flow change? How?

Experiment 77: What causes the water to flow from the siphon?

Take a two-foot length of rubber tubing or a glass tube bent into a U shape, with each arm about one foot long. Fill the tube with water, keep your finger over one end, and invert the tube into two jars of water, as shown at the left in Figure 335. Remove your finger and raise one jar of water a few inches above the table. What happens? Replace the jar on the table. What happens? How do the lengths of the water columns in the two arms of the tube above the surface of the water in the jars compare when the siphon ceases to flow? Measure them. Note that when the water flows through the siphon, it flows toward the side having the longer arm above the surface of the water in the jar. In the syphon at the right (Figure 335), which is

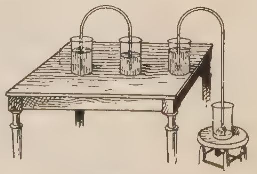


Fig. 335. Siphon Experiment

heavier, the water in the left arm or the water in the right arm? From which tube will the water, therefore, flow out first on account of the pull of gravity? If it flows out of one arm, what condition would result in the top part of the tube? How will the air pressure on the water in the left jar prevent such a condition?

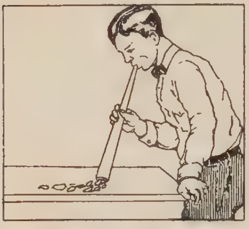


Fig. 336. Experiment 78

Exercise 3. Name as many uses of the siphon as you can.

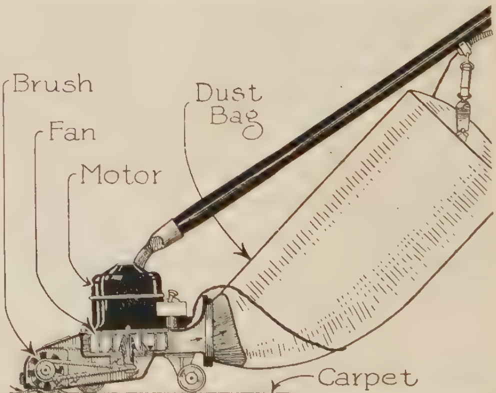
Exercise 4. Why do you suck the air out of the siphon to start it?

Exercise 5. Why does the siphon continue to flow after being started?

The vacuum-cleaner makes use of air pressure. One of the handiest devices around the home is the vacuum-cleaner.

Experiment 78: How can air pressure pick up light materials?

Roll a large sheet of paper into a cylinder about half an inch in diameter. Place the cylinder over small pieces of paper, as in Figure 336. Suck the air out of the paper tube by inhaling rapidly. What happens to the small pieces of paper? From your study of air pressure explain why this happens. (See page 55.)



Courtesy Hoover Co.

Fig. 337. A Vacuum-Cleaner

When some air is removed from a space, the remaining air becomes thinner and the pressure less. Such space is called a *partial vacuum.* The outside air is forced into such space by the surrounding air pressure. As the air rushes in, it carries along light materials like paper or dust, just as running water carries stones or sand.

A common form of vacuum-cleaner is shown in Figure 337. The important parts of the machines are labelled. Study the parts to understand the following explanation of the machine. As the electric motor rotates, it turns the fan. The fan pumps air into the dust bag. This produces a partial vacuum in the chamber around the fan, and the air from the outside rushes in, carrying with it the dust which has been loosened by the brush. The dust is then blown with the air into the dust bag. The air escapes through the fine mesh of the bag, but the dust is held.

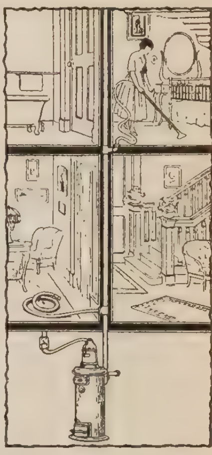


Fig. 338. A Vacuum Cleaning-Machine

See Figure 339 to understand how it works.

In large buildings, such as stores, hotels, clubs, and office buildings, and also in many modern homes, the vacuum-cleaner is often placed in the basement (Figure 338). Metal pipes connect the different rooms with the machine, and the cleaning tool can be attached to these tubes by means of a long rubber hose. The construction and operation of the machine are shown in Figures 338 and 339. The vacuum produced by the machine causes the air to rush in through the cleaning tool and pick up dust and dirt from the floor.

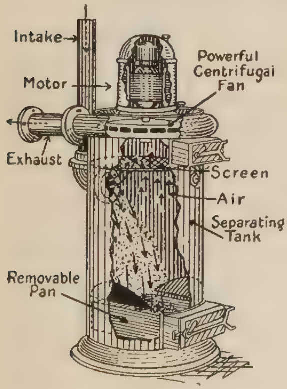


Fig. 339.
The Vacuum Machine

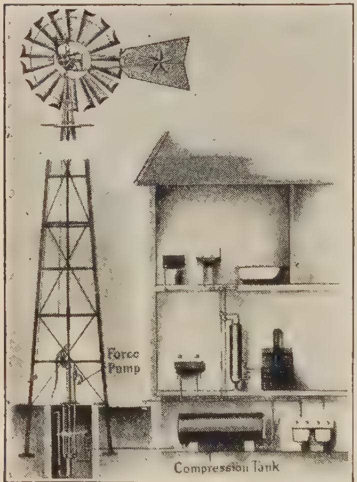
As the fan is rotated by the motor, the air is thrown out through the exhaust. This produces a partial vacuum in the intake pipe which leads to the cleaning tool.

Exercise 6. Why is the "vacuum-cleaner" not a vacuum cleaner?

Exercise 7. Why is cleaning with the vacuum-cleaner more sanitary than sweeping with a broom?

PROBLEM 3: HOW DOES COMPRESSED AIR WORK FOR US?

Compressed air serves us in many ways. When air is compressed into a container, it exerts an outward pressure. You recall that the ordinary air pressure is about 15 pounds per square inch. Now, if two cubic feet of air are forced into a vessel having a space of one cubic foot, the air pressure inside is 30 pounds per square inch; or if 10 cubic feet of air are forced into the vessel, the outward pressure of the compressed air is 150 pounds per square inch. You see, then, that compressed air may exert a great pressure. This pressure can be used in a number of ways.



Courtesy Flint and Walling Co.

Fig. 340.

A Pneumatic Water System

The force pump forces water into the tank, compressing the air above it. This air then forces water through the pipes to the hot-water heater and the bath-room, or directly to the kitchen sink. (*Pneumatic* means "air-operated.")

Perhaps the most common use of compressed air is for inflating, or "blowing up," automobile tires. Compression pumps, like that shown in Figure 333, force air into heavy-walled tanks. Tubes with valves at the ends lead from these tanks. From these tubes we take the air to inflate our tires to a pressure of 40, 60, or 80 pounds. The pressure in the tire really lifts the automobile, so great is its force. At the same time it improves the riding qualities of the automobile.

Other common uses of compressed air are found in compressed-air engines, in drills used in machine shops, mines, and stone quarries, in pneumatic riveters, and in forcing water from tanks to the rooms of houses (Figure 340).

The air-brake uses compressed air. Perhaps the most useful compressed-air device is the *air-brake* for trolley cars and trains (Figure 341). On trains a compression pump on the engine forces air into a large tank or reservoir, keeping the air at a pressure of about 75 pounds per square inch. This reservoir is connected by means of pipes and by air-tight couplings between cars to a smaller reservoir and the brakes under each

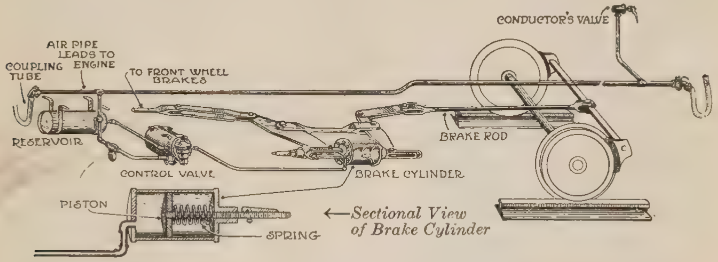


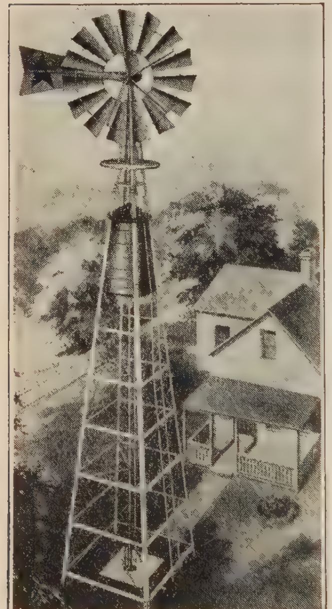
Fig. 341. An Air-Brake System

car. While the pressure in the engine reservoir is at 75 pounds per square inch, the control valve is in such position that the two reservoirs are connected by the air-pipe. If the engineer opens the valve on the air-pipe connecting the engine reservoir to the car reservoir, if the couplings between cars become separated, or if the air-line is broken or cut, air escapes, and the pressure in the air-pipe becomes less. Whenever this happens, the pressure in the car reservoir turns the control valve in such a way that the compressed air enters the brake cylinder and forces the piston to the right with great force. The piston rod operates the brake levers, sets the brake shoes against the wheels, and stops the train. When the air is again turned on from the engine reservoir and the pipes are air-tight, the control valve turns so that the car reservoir is connected with the air-pipe, and the compressed air in the brake cylinder can escape. The heavy spring in the brake cylinder, which was compressed, now opens, pulling the piston rod back and releasing the brakes.

Exercise 8. You often hear a whistling noise under a car when a train is about to start. What causes it?

Exercise 9. Railroad cars come to an abrupt stop if the train happens to break apart. Explain.

Exercise 10. What would be the force against the cylinder of an air brake 8 inches in diameter if the pressure in the car reservoir is 60 pounds per square inch? (The area of a circle equals $\frac{22}{7}$ times the radius times the radius.)



Courtesy Flint and Walling Co.

Fig. 342. A Modern Windmill

The windmill pumps water in to the tank, from which it is supplied to the house.

PROBLEM 4: HOW IS THE FORCE OF WIND HARNESSED?

In country districts you often see a type of machine, the windmill (Figure 342), which utilizes the force of moving air to pump water and run machinery. The air strikes the wooden or steel blades, or *vanes*, of the wheel, causing the wheel to rotate just as a pinwheel (Figure 343) is made to turn by being blown upon or by the force of the air which rises over a warm radiator or stove. To the shaft of the wheel are attached two small gear wheels. These mesh with two larger gear wheels on a second shaft. A short arm extends outward from each of the large gear wheels and is attached to the wheel at a point a few inches from the center. Such an arrangement is called an *eccentric*, meaning "off center." Connected to the two short arms are two heavy eccentric rods, which extend upward and are held together by an arm across the top. The pump rod is attached to this arm, and, as the wheel turns, the piston rod of the pump is moved up and down (Figure 344).

The speed of the windmill depends upon the speed of the wind and upon the direction from which the wind strikes the blades. The pressure of a wind blowing at 30 miles an hour is about 5 pounds per square foot; at 50 miles an hour the pressure increases to about 15 pounds per square foot. If there are 30 vanes on a windmill, each three feet long and one-half foot wide, and all of the force of a 30-mile wind could be utilized, the force would be $3 \times \frac{1}{2} \times 30 \times 5$, or 225 pounds. As a matter of fact, the wind does not strike directly against the blades, but at an angle, and some of the force is wasted. The fan of the windmill keeps the wheel in such a position that the force of the wind may be utilized to the greatest advantage when the mill is running. The wheel is so attached that it can always swing into the wind. Thus, whether or not the windmill is running, the fan is always pointing in the direction toward which the wind is blowing. There are also devices for stopping the wheel when the power is not needed.

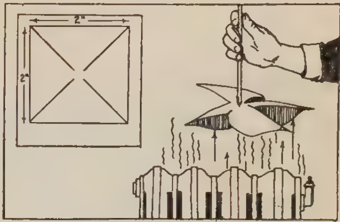


Fig. 343. A Pinwheel

The inset in the upper left corner shows how to cut a piece of paper to make the wheel.

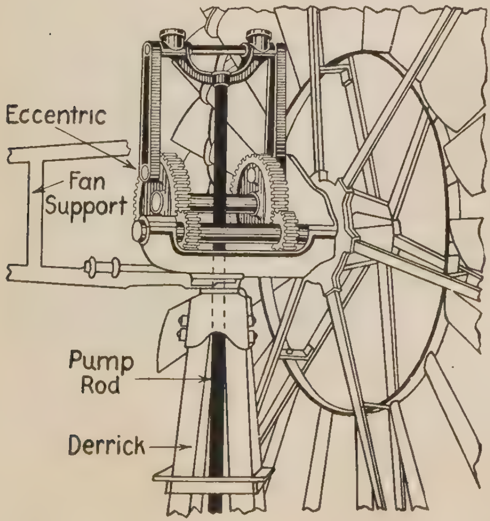


Fig. 344. Windmill Operation

PROBLEM 5: HOW IS WATER PUT TO WORK?

The overshot water wheel was formerly much used. For hundreds of years the overshot water wheel was used to grind grain into flour and to saw wood. Even today in some parts of the country this device is found (Figure 345). A dam is built across a stream and the water is led through a wooden or metal *flume* to the top of the wheel. The buckets or paddles of the wheel are turned by the weight of the water. As the buckets or paddles come to the bottom, they empty the water into the stream below and are carried upward by the weight of the water in the other buckets. Such a machine, as you see, is really a wheel and axle. The "work in" is the product of the weight of the water and the distance which it moves while in the buckets. Some water is spilled, of course, but the source of energy is cheap, and the efficiency of the machine may be as high as 80 to 90 per cent.

Fig. 345. An Overshot Wheel

As the shaft of the wheel turns, it operates the grain grinder within the mill. A gate at the dam controls the flow of water through the flume.

The turbine is more efficient than the water wheel. The turbine is a newer and more efficient device for harnessing the force of water at a dam. One kind of turbine is shown in Figure 346. The concrete dam is at the right. The water flows through the gate and enters the turbine below. Inside the turbine, stationary blades direct the water against the blades of the rotating part. The rotating part, or *rotor*, as it is called, turns the shaft to which it is attached. This shaft extends upward to the dynamo in the room above the turbine.

There is so little waste of power in this type of turbine that the efficiency may be considerably above 90 per cent.

Exercise 11. The turbine is more efficient than the overshot water wheel. Why?

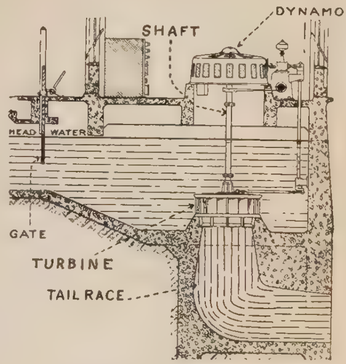


Fig. 346. A Modern Turbine

Where the water is not over 25 feet deep, this kind of turbine is most commonly used. Compare with Figure 423, page 432.

Undershot water wheels are also used. Anyone who has tried to wade a swift stream or who has been doused with water coming from a hose knows that the energy of running water depends upon the amount of water and the speed with which it moves. The earliest device for using the force of running water was probably the *undershot water wheel* (Figure 347). This is commonly used in streams where there is a large amount of water available. Much force is wasted in such an arrangement, for only the water which strikes the paddles or vanes can do work. As a result of this waste, most undershot wheels are only from 20 to 30 per cent efficient.

Ewing Galloway

Fig. 347. An Undershot Wheel

This is all that remains of an old mill built over one hundred years ago.

One type of undershot wheel, however, is very efficient. This is the *Pelton wheel* (Figure 348), which is used to a great extent in mountainous regions where the water can be brought from a place far above the wheel. The water is led down through a pipe ending in a nozzle,

much like the nozzle on a garden hose, and strikes the cups at the end of the vanes. The water comes out of the nozzle at a high speed and drives the wheel very rapidly. Little force is wasted by this arrangement, and the efficiency of the wheel may be as high as 85 per cent. Like all water wheels the Pelton is a wheel-and-axle machine. The force is applied at the cups, and the shaft of the wheel is turned, transmitting the energy for running machinery.

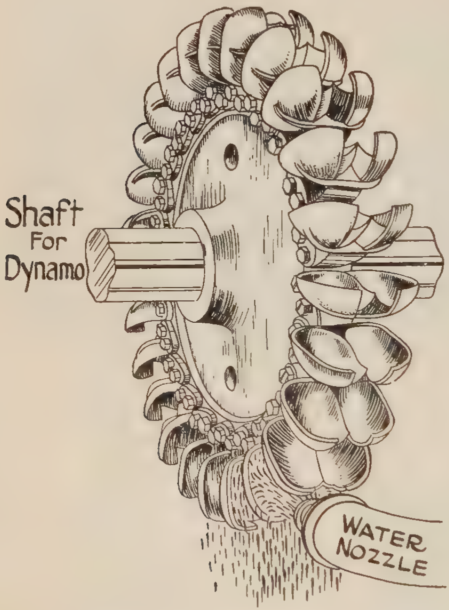
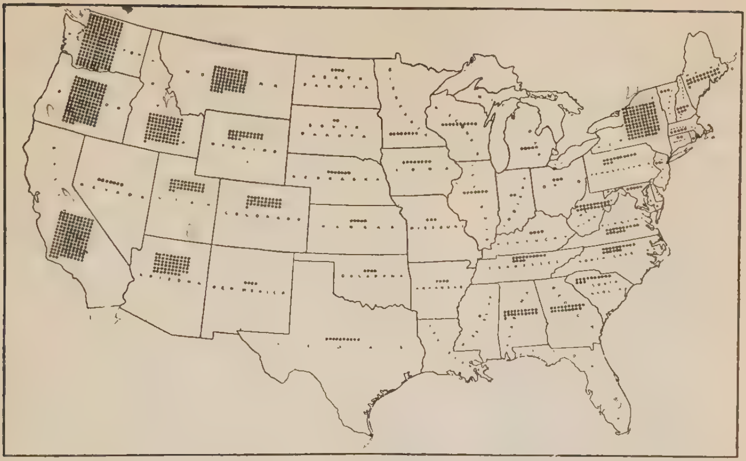


Fig. 348. A Pelton Wheel

By means of water wheels and turbines enormous water power is utilized to generate electricity, both in our own country and in foreign countries. This electricity saves our fuel, gives us powerful electric engines for mountainous regions (Figure 479, page 481), helps to keep our cities clean by eliminating smoky furnaces, lights our cities, and runs most of our street and interurban cars. Figure 349 will give you some idea of the large amount of water power which may be developed in our country, and Figure 350 shows you what part of the available power has been put to work.

Exercise 12. In what ways is water power important to man?

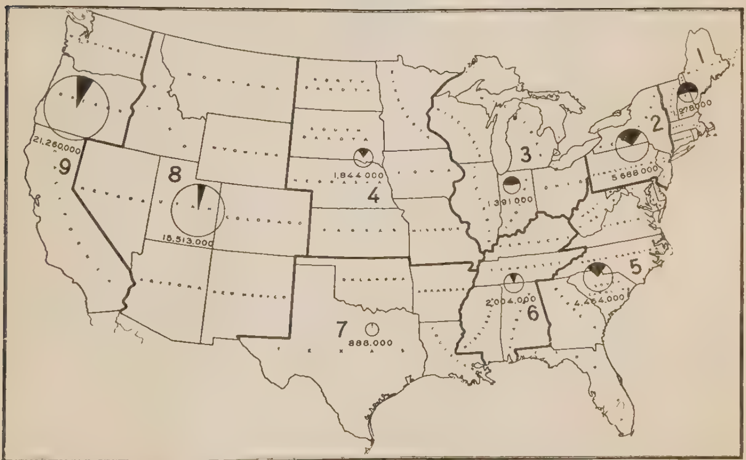
Exercise 13. Why is each of the water wheels described in this problem a machine of the wheel-and-axle type, and how is the force of the water applied to each?



Courtesy Federal Power Commission

Fig. 349. Available Water Power in the United States

Each dot shows that 50,000 horse-power can be developed. The total for the entire country is 55,000,000 horse-power.



Courtesy Federal Power Commission

Fig. 350. Water Power Developed in the United States

The circles and the numbers below them show the available water power in nine regions of our country. The black area of each circle indicates the proportion of the water power that has been developed.

PROBLEM 6: HOW IS WATER USED TO TRANSFER FORCE?

The hydraulic press is a simple machine. The *hydraulic press* is a machine for exerting an enormous force by means of a much smaller force. It is used to bale cotton and paper, to roll hot iron into various forms like railroad rails or sheet iron, to punch holes in metals, to press oil out of seeds, to test the strength of concrete or metals, and to do hundreds of other necessary tasks. Figure 351 shows a hand-operated hydraulic press. Compare this with the section-drawing shown in Figure 352. It consists of two heavy-walled cylinders of different diameters, connected with each other by means of a heavy metal tubing. Each cylinder is fitted with a piston. The piston of the small cylinder is operated by a lever. The cylinders and connecting tube are filled with water, the smaller cylinder being connected with a water-supply source. When the piston in the small cylinder is pushed downward, water is forced into the large cylinder, causing the large piston to move upward, and exert a great force.

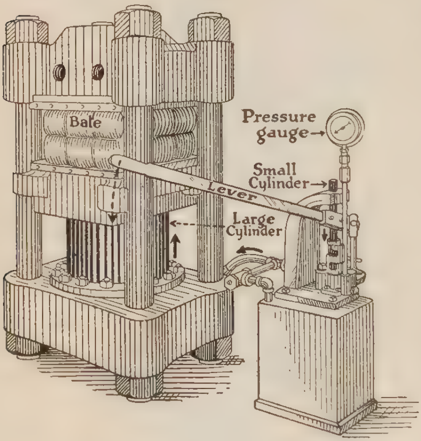


Fig. 351. A Hydraulic Press

As the lever is moved downward, the small cylinder is forced into the tank below. Water is forced as shown by an arrow into the tank under the large cylinder, pushing this cylinder upward and compressing the bale.

The force is multiplied by such a machine. Suppose that a force of 100 pounds is applied to the small piston by pushing down on the lever, and suppose also that the small piston has an area of one square inch, while the area of the large piston

is 10 square inches. If 100 pounds of force are applied to the small piston, there will be 100 pounds of pressure against the water below the piston. Since the pressure in water is the same in all directions at any depth, there will be a pressure of 100 pounds on every square inch of surface inside the container. Water, being free to move and being non-compressible, will transmit this pressure to every square inch of water in the large cylinder and, therefore, against the large piston. If the large piston has an area of 10 square inches, as you supposed at the start, there will be 100 times 10, or 1000 pounds of force against the large piston. You see that the force exerted has been multiplied ten times by such arrangement. The pistons can be made of different diameters; so the force may be multiplied as many times as the cross-section of the large piston is greater than the cross-section of the small piston. It will be seen that the small piston must move ten times as far as the large piston. While the force is multiplied ten times, the distance through which the force is exerted by the large piston is only $\frac{1}{10}$ as great as the distance through which the applied force moves.

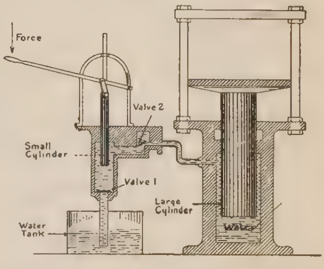


Fig. 352. Sectional View of a Hydraulic Press

Exercise 14. A hydraulic press does not save work. Explain, keeping in mind the scientific meaning of the word work.

Exercise 15. Compare the hydraulic press which you just studied with a ten-strand pulley system, considering the mechanical advantage of force of each and the distances through which the force in and force out move. (See page 332.)

Exercise 16. If the lever arm in Figure 352 is six feet long, the distance from the fulcrum to the piston one foot, the area of the small piston four square inches, and the area of the large piston 100 square inches, what force can be exerted with the device by applying a force of 50 pounds at the handle of the lever?

PROBLEM 7: WHAT IS THE MEANING OF THE TERM "HORSE-POWER"?

Probably everyone has heard that an automobile engine has a certain horse-power or that the water at a waterfall can develop so many horse-power. What is the meaning of the term horse-power and how is it measured?

"Horse-power" is the unit for measuring power. You recall that the terms force, work, energy, and power have different meanings. Force moving through a distance does work; anything which has the ability to do work possesses energy; the rate at which work is done is known as power. To measure force, work, and energy you used certain units. Similarly, to measure power you must have a unit. The unit most commonly used is the horse-power.

Fig. 353. Horse-Power

If the horse pulls the load with a force of 150 pounds, and walks 220 feet in a minute, how much work does he do in one minute?

The term horse-power originally referred to the rate at which a horse works (Figure 353). A horse walking at the rate of two and one-half miles an hour for eight to ten hours a day should not be required to pull more than one-tenth or one-eighth of its own weight. If a horse weighs 1200 pounds and pulls one-eighth of its weight, it must pull 150 pounds. In one hour the horse would do $150 \times 5280 \times 2\frac{1}{2}$, or 1,980,000 foot-pounds. Divide this by 60 and you have 33,000 foot-pounds per minute. Scientists have agreed to take this rate of work as the unit of power and call it the horse-power.

When we say an engine has a horse-power of twenty-five, we mean that it can do $25 \times 33{,}000$ foot-pounds of work per minute. Similarly, when it is said that 500,000 horse-power may be developed by the water at the Keokuk dam on the Mississippi

River, we mean that the water can do 500,000 times 33,000 foot-pounds of work per minute. Stated in other terms, this means that the power which may be developed at Keokuk could lift a weight of 100 tons over 15 miles high in one minute. You see what a tremendous power the water at a single dam may have.

Exercise 17. If the work done at the present time by the turbines at Keokuk is about 10,000,000,000 foot-pounds per minute, how many horse-power are developed?

Exercise 18. Knowing your weight and the height of a stairway, walk up the stairway at your ordinary rate, noting how many seconds are required to reach the top. Calculate how many foot-pounds of work you did each minute. Take the average of two trials. What fraction of a horse-power expresses the rate at which you worked? Compare your results with those of someone who is heavier or lighter than you.

Review Exercise on Unit XII. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit XII and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT XII

1. Make a drawing of a double-acting air-compression pump. Compare it with a double-acting force pump for water.

2. Explain why gasoline can be removed from a tank more rapidly with the long hose than with the short hose, as shown in Figure 354.

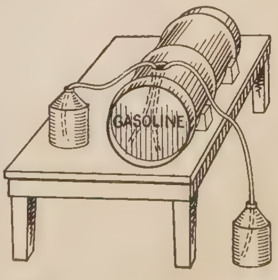


Fig. 354. Using the Siphon

3. How could you empty the water from a gold-fish bowl and refill the bowl without moving it?

4. Can you show by a drawing how you could make a siphon of glass tubing for removing an acid from a large container so that you could start the siphon without the danger of getting acid in your mouth?

5. Dams are built thicker at the bottom than at the top. Why?

6. What is the pressure per square foot against a dam at a depth of 60 feet? Remember that water pressure, like air pressure, is the same in all directions at any depth (one cubic foot of water weighs 62.4 pounds). Explain your answer.

7. Take apart a bicycle or automobile pump and see how it works. Make a section drawing of the pump and explain from the drawing how it works.

8. Set up an apparatus (Figure 355) with the upper bottle about one-fourth full of water. Open the pinch-clamp so water may run out of tube *A*. Explain what you see.

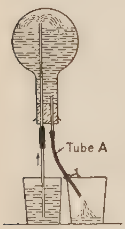


Fig. 355. An Automatic Fountain

9. Examine your vacuum-cleaner at home and see if it operates as the one described. If it does not, how does it work?

10. Make a siphon of glass tubing like that in Figure 356. Lower it into a tall jar of water as shown, and observe that the siphon starts automatically. Can you explain why it works?

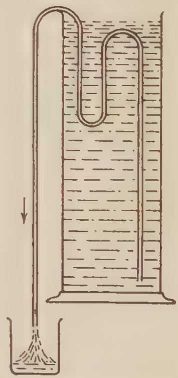


Fig. 356. A Siphon

11. Consult Figure 349 and make a list of the states in our country in the order of their available water power.

12. Would it be possible to siphon water from a stream into a reservoir below the surface of the stream if the pipe line had to run over a bank sixty feet high?

UNIT XIII

USING STEAM AND EXPLODING GAS FOR POWER

Preliminary Exercises

1. How did steam power help to supply the food which you ate for breakfast this morning?

2. How does steam power help to provide the clothing you wear?

3. Make a list of the ways in which steam works for us.

4. How can the engineer of a train stop the train quickly?

5. A locomotive has an efficiency of only 6% to 10%; that is, only 6% to 10% of the energy of the coal is used to pull the train. What becomes of the "lost" energy?

6. What sources of power, other than steam, are used for transportation on land or water?

7. Make a list of the uses of the gas engine.

8. What are the important parts of a gas engine?

9. What instruments does one find on the dashboard of an automobile? What is the purpose of each?

10. What are the principal differences between a gas engine and a steam engine?

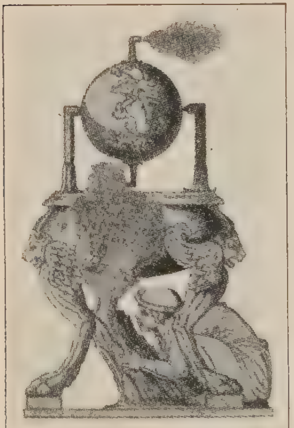
11. For what purposes are horses better than a gasoline tractor? Than a truck?

12. The gasoline truck and automobile have replaced the horse for many uses. Why has this happened?

THE STORY OF UNIT XIII

In man's search for sources of energy to run his machines and to improve his methods of transportation, he has come to use the forces of air, water, steam, exploding gas, and electricity. You have learned how air and water are used. In a later unit you will see how electricity is generated and utilized. In the present unit you will consider two important forces, steam and exploding gas.

There is probably no force which does as much of our work as steam. Stationary steam engines run many machines in factories, generate electricity, help to build roads, dig canals, and in a variety of other ways save our strength and our time. Similarly, steam engines on locomotives, steamships, and automobiles furnish the force for rapid travel and transportation. How important steam is can be appreciated best when you think how different life would be without the steam engine and its numerous uses. Think, for example, of the difference between the methods of travel in the early days of our country and those of the present. To go from New York to Philadelphia required a hard two days' trip by stagecoach. Now a man may eat breakfast in Philadelphia and within a few hours be in New York City ready for his work. Or, he can travel half-way across the United States in the same time which was required to go from Philadelphia to New York by stagecoach.



From *Growth of the Steam Engine*, by R. H. Thurston. D. Appleton & Co., publishers

Fig. 357. Hero's Engine

The water is heated in the large bowl. The steam rises through the pipes and enters the sphere at the sides. As the steam escapes, the sphere is forced to rotate.

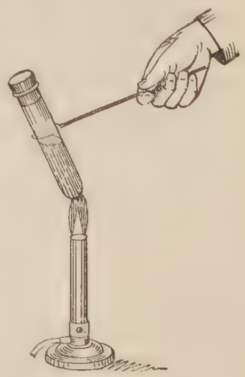


Fig. 358. Generating Steam

The development of the use of steam has been very rapid. Though a Greek, named Hero, constructed a toy engine as early as 150 B.C. (Figure 357), no practical use of steam was made before 1633 A.D., when an engine was used to pump water from coal mines in England. In 1784 James Watt, an English

scientist, constructed an engine much like those which we use today. Following that date many stationary engines were used, but Fulton was the first to make use of steam to propel a water vehicle, when, in 1807, he made his famous trip from New York to Albany in the *Clermont*. (See Figure 481, page 483.) A little later, in 1829, Stephenson completed the *Rocket*, the first really successful locomotive for land transportation.

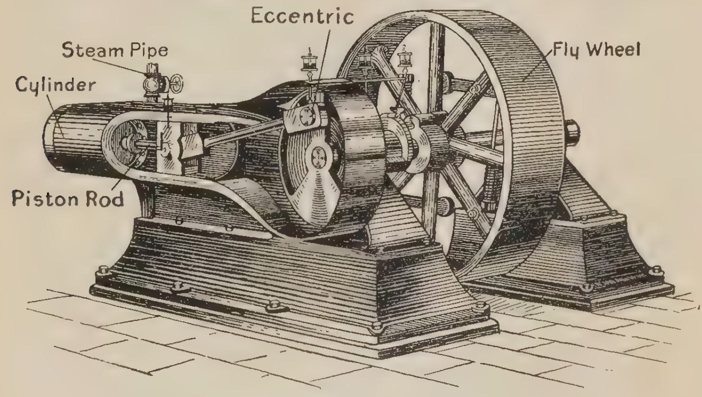
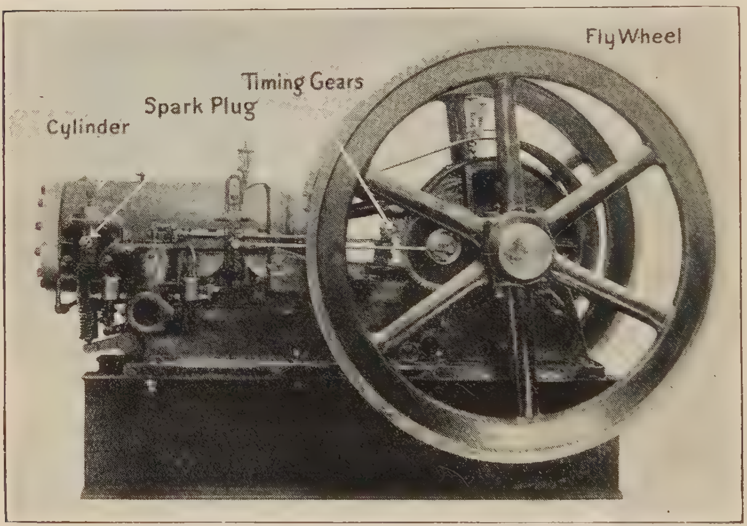


Fig. 359. A Steam Engine
This is a common type of stationary steam engine.

All forms of steam engines depend upon the energy of steam molecules. As water is heated, its molecules move more rapidly until some of the water changes to steam. (See page 269.) These steam molecules possess energy and can do work. Thus, if you generate steam in a test tube fitted with a stopper (Figure 358), the stopper is blown from the tube by the force of the millions of molecules of steam which strike it. In a similar way steam may be generated by the fire under a steam boiler. The steam may then be led by pipes into the cylinder of a steam engine (Figure 359). Here it exerts a tremendous pressure against the piston and moves the piston. By allowing the steam to enter the cylinder first on one side of the piston and then on the other, the piston is moved back and forth. A rod connected with the piston turns a flywheel.

The importance of the gas engine as a means of power is almost as great as that of the steam engine. The first practical gas engine was not invented until 1876. Since that time its development has been one of the most marvelous achievements of modern times. Machines of all kinds are operated by it.



Courtesy Foos Gas Engine Co.

Fig. 360. A Stationary Gas Engine

This type of gas engine is used to run machinery of all sorts.

Thus, on the farm it is used to saw wood, churn butter, thresh and grind grain, pump water, and run dynamos which furnish electric light. Often the engine is portable and can be moved from place to place to serve a great number of uses. In factories it is of similar importance. Perhaps its most commonly seen use is in the automobile, motorboat, and airplane, where it furnishes the power to drive these vehicles. Many ocean-going ships are coming to use the gasoline engine.

The gas engine depends for its power upon exploding gas. A proper mixture of combustible gas and air is very explosive. Thus, if you mix some illuminating gas and air in the proper

proportion in a wide-mouthed bottle and bring a flame to the mouth of the bottle, an explosion results. During such an explosion the gases formed by combination of the oxygen and the elements of the gas are greatly heated and expand rapidly. If the gas and oxygen are compressed in a closed space, a great

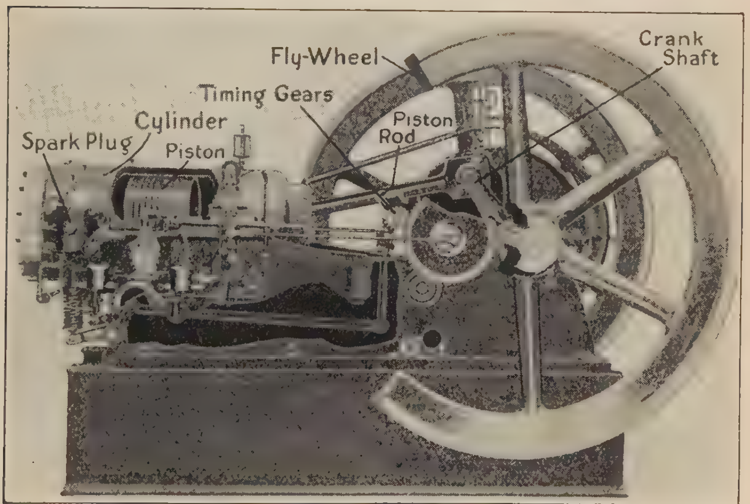


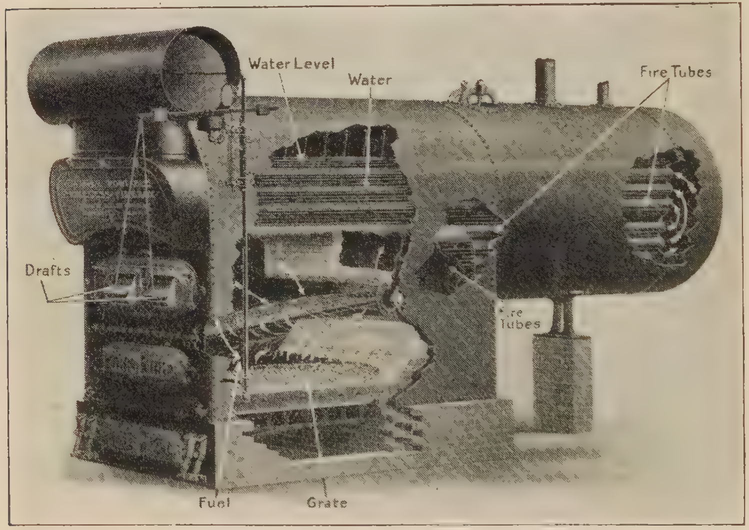
Fig. 361. Sectional View of a Gas Engine

force outward is produced by the explosion. Such force may be utilized within a cylinder of a gas engine (Figure 360) to move the piston. The piston may be connected by a rod to a *crank shaft* (Figure 361) and thus made to turn the wheel.

You see that there is some similarity between the steam engine and the gas engine. In the steam engine the driving force is produced by the energy of the moving steam molecules which get their energy from the heat of the fire under the boiler. In the gas engine the driving force comes from the expansion of the gases which are produced by combination of the mixture of gas and oxygen. The ordinary automobile engine uses gasoline, which is changed to a gas and mixed with

air in the *carburetor* before the mixture is compressed and exploded in the cylinder. In both engines the piston moves backward and forward or upward and downward and is connected by a piston rod to the machine which it operates.

Each kind of engine has certain advantages over the other. The steam engine is not so complicated and can be kept in



Courtesy Kewanee Boiler Co.

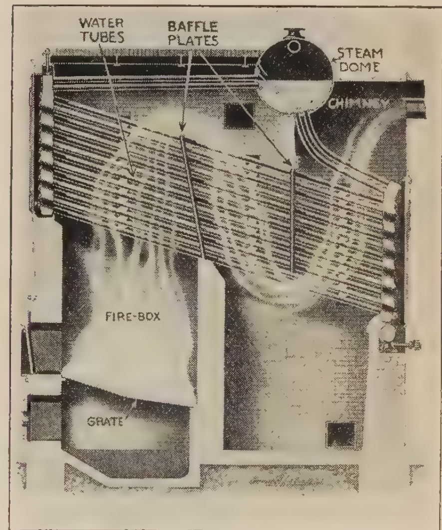
Fig. 362. A Fire-Tube Boiler

Since there are many tubes being heated by the hot gases from the fire, the water can be changed to steam very rapidly.

running condition much more easily than the gas engine. It does not require careful adjustment of parts like the carburetor, electric system, and gears of the gas engine. This makes it more reliable in operation. On the other hand, the gas engine is light; it weighs only one-half or one-third as much as a steam engine of the same power. Thus, for use in automobiles and airplanes, where a light, compact, and efficient power plant is required, the gas engine is superior to the steam engine.

PROBLEM 1: HOW IS STEAM GENERATED FOR POWER?

The steam which is necessary to run a steam engine is generated in boilers by heating water. A common type of boiler is the *fire-tube boiler* (Figure 362). It consists of iron tubes fastened inside a large cylinder made of steel plates from one-half to seven-eighths of an inch in thickness. The tubes extend the full length and open at each end through the heavy steel ends of the boiler (Figure 362). They may vary from two to four inches in diameter in boilers of different size. The boiler is so placed and constructed that the hot gases from the fire pass through the iron tubes on their way to the smokestack and heat the water which is in the spaces around the fire tubes. Since the boiler is only partly filled with water, the steam which is formed can collect in the space above the water level. Pipes leading from the top of the boiler carry the steam to the engine.



Courtesy Page Water Tube Boiler Co.

Fig. 363. A Water-Tube Boiler

The baffle plates prevent the hot gases from passing directly to the chimney.

Another form of boiler, which is used to generate steam in large quantities for stationary engines, is the *water-tube boiler* (Figure 363). In this boiler the water is in the tubes, and the hot gases from the fire pass over these tubes, heating the water inside. The steam collects in the upper part of the steam dome above. This very efficient type of boiler is used in many large steam-producing plants.

Exercise 1. Why are water-tube and fire-tube boilers used instead of cylindrical boilers which are heated by a fire underneath the cylinder?

Boilers are fitted with safety valves. Since steam may exert a tremendous pressure in the boiler when the fire is too hot, there must be some way to avoid the bursting of the boiler. To prevent this, boilers are fitted with *safety valves.* Figure 364 shows one kind of safety valve. This is called the *weight and lever safety valve.* The device is fitted to the top of the boiler. The cone-shaped valve fits against the valve seat and is held down by the weight on the lever. By adjusting the position of the weight, any desired force can be exerted downward on the valve. When the pressure of the steam in the boiler becomes greater than the downward pressure of the valve, the valve is forced open, and the steam escapes through the blow-off pipe until the proper pressure is reached in the boiler.

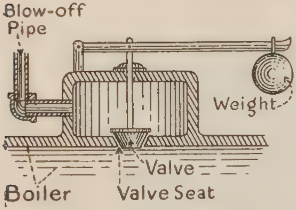


Fig. 364. A Safety Valve

Find the lever in this device. Is it a first-class, second-class, or third-class lever? Give your reason. (See page 327.)

Exercise 2. If the weight in Figure 364 weighs 20 pounds and is placed at a distance of 12 inches from the fulcrum, while the distance from the fulcrum to the valve stem is 4 inches, what force must the steam exert to open the valve?

Locomotives require an enormous steam pressure. The great steam pressure required to run large locomotives is possible because when the water is heated in an enclosed boiler, the boiling point of the water is changed, as shown in Experiment 79.

Experiment 79: (*To be done by the instructor*) **How does the boiling point of water depend upon the pressure?**

(*a*) Pour some water in a flask or in a tin can with a narrow neck. Fit a one-holed stopper with a thermometer and arrange the apparatus as in Figure 365. Heat the water until it boils, holding the

thermometer so the stopper does not close the mouth of the vessel. The temperature will be about 100° C. or 212° F., depending upon the altitude of your school above sea-level. Now push the stopper slowly and gently (not securely) into the mouth of the flask, allowing a little steam to escape. What effect does this have upon the temperature? (*Caution:* Stand back an arm's length.)

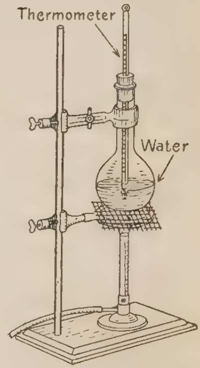


Fig. 365
Pressure and Boiling Point

(*b*) If mercury and glass tubing are available, arrange an apparatus as shown in Figure 366. Bring the water to boiling and note the temperature. Then insert the stopper tightly and heat the flask with a very small flame. The thermometer will give you the temperature, and the difference in level of the mercury in the two arms of the tube will give the pressure above the atmospheric pressure. You can take several different readings of the thermometer, and at the same time take a corresponding reading of the mercury levels by placing a ruler back of the arms of the tube. (A difference in the mercury level of one inch is equal to a pressure of .49 pound.) From these readings you can see how the boiling point varies with the pressure.

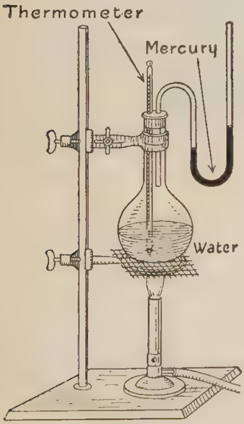


Fig. 366
Pressure and Boiling Point

Water changes to steam at approximately 100°C. or 212°F., when heated in an open vessel. It cannot be heated above this temperature, for as more heat is added, more water changes to steam. This change of a liquid to a gas takes up the additional heat, and the temperature of the water remains at about 100°C. or 212°F. In the boiler the steam cannot escape; it therefore exerts a pressure against the surface of the water. The water cannot change to steam so rapidly because of this pressure, and the added heat from the fire box

increases the temperature of both the water and the steam. The speed at which the molecules of steam move depends upon their temperature; the higher the temperature, the greater the speed.

In locomotives the temperature of the steam is often as high as 400°F. The need for this great pressure is clear when we consider that some of the giant locomotives are able to draw a loaded train a mile and a quarter long, weighing 17,000 tons.

Exercise 3. Summarize the important ideas in Problem 1.

PROBLEM 2: HOW DOES STEAM RUN AN ENGINE?

The steam engine is a complex machine. Figure 367 shows the parts which are essential to the engine. The steam comes from the boiler through a pipe and enters the *steam chest*, which

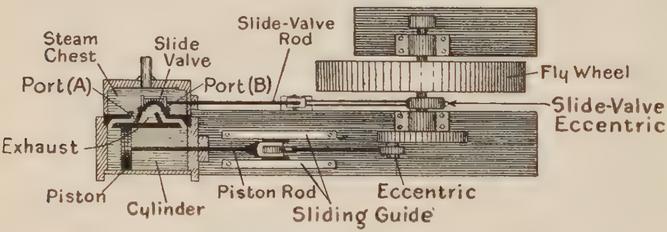


Fig. 367. Sectional View of a Steam Engine

This is what the engine in Figure 359 would look like if cut away and seen directly from above.

is an iron box located at the side of or directly above the *cylinder*. In the bottom or side of the steam chest are three openings. Two of these lead to the cylinder, and are called the *ports*. On the bottom of the steam chest rests a heavy metal block which is hollowed out on the lower side and which slides back and forth when pulled or pushed by the *slide-valve rod*. This metal block is called the *slide valve*, and is large enough always to cover one port and the *exhaust* through which the used steam leaves the engine. Inside the cylinder is a circular disk called the *piston*, to which is attached the *piston rod*.

The piston rod is attached to the flywheel shaft by the eccentric. Any motion of the piston rod will turn the flywheel. As the flywheel rotates, the slide-valve rod is moved backward and forward, opening and closing the ports at the proper time.

How the engine works. Modern steam engines are double-acting. Steam enters the steam chest from the boiler (Figure 367). From here it passes through port (*A*) and enters the cylinder, where it expands, forcing the piston toward the other end. Any steam in the other end of the cylinder is forced out of port (*B*) into the hollow of the slide valve and escapes through the exhaust, which opens into the outside air. As the piston moves, the piston rod, kept in a horizontal position by the *sliding-guide*, turns the wheel by means of the piston-rod eccentric. When the flywheel rotates, the slide-valve eccentric moves the slide valve toward the opposite end of the steam chest. By the time the piston has reached the left end of the cylinder, the slide valve has moved far enough in the opposite direction to uncover port (*B*) and connect port (*A*) with the exhaust. Steam now enters the cylinder from the steam chest through port (*B*) and forces the piston in the opposite direction, causing the wheel to continue its rotation. At the same time the steam in the right end of the cylinder is forced out into the air through the exhaust. As the piston reaches the right end, the slide valve has moved to the opposite end of the steam chest, and steam enters port (*A*), driving the piston in the opposite direction. And so the back and forth motion of the piston is changed to the circular motion of the wheel, which continues to rotate so long as steam passes from boiler to steam chest. This flow of steam is controlled by a valve operated by a lever called the *throttle*. (See Figure 368.)

Experiment 80: How does a toy steam engine work?

Bring a toy steam engine to the classroom if there is none available in the room. Examine it carefully. Start the fire and study the operation of the engine. Make a section drawing showing the fire, the boiler, and the engine.

Flywheels are necessary on engines. The flywheel to which the piston is attached is a necessary part of the steam engine. It is very heavy, and it takes an enormous force to set it in motion. As its speed increases, it becomes more and more difficult to stop. This tendency of any object to remain in motion or to remain stationary is called *inertia.* The flywheel is a necessary part of the steam engine because it insures a constant speed. When the piston is at either end of the cylinder, there is no steam pressure on it. (Examine Figure 367 to see why this is true.) These are called the *dead points.* The inertia of the heavy flywheel moves the piston past these points, and so the steam can again exert pressure upon the piston. If it were not for the flywheel, the engine would slow up at the end of each stroke, and if the load were very heavy, it might stop. A belt may be run by the flywheel, as shown in Figure 333, page 349, or a small belt wheel may be rigidly attached to the axle of the flywheel. In some cases gears are used to transfer the energy of the wheel to machinery.

Exercise 4. Make a drawing of the steam engine like that shown in Figure 367, but with the piston at the other end of the cylinder. Show the position of the slide valve and the direction of the steam through the engine.

PROBLEM 3: HOW DOES A STEAM ENGINE RUN A LOCOMOTIVE?

The ordinary locomotive has two engines, one on either side in front of the drive wheels and just outside the small wheels. Figure 368 shows one side of a locomotive. The piston rod is connected with an eccentric on the middle drive wheel. A long heavy bar, called the Johnson bar, is attached to this eccentric and to the eccentrics of the other drive wheels. As steam drives the piston back and forth, the drive wheels rotate. The friction between the wheels and the track is so great that the wheels cannot slip, and the locomotive is forced to move. The pistons, slide valves, and eccentrics in the two

engines on either side of the locomotive are so arranged that when one engine is passing the "dead point," the engine on the other side is exerting its greatest force in rotating the wheels. The locomotive, therefore, cannot so stop that both engines are at their "dead points," and it is always ready to move when the engineer opens the throttle valve and allows steam to pass to the steam chests.

In order to keep up high steam pressure, a strong draft is required through the fire box. The smokestack is too short to be of value in this respect. (See page 231.) This in-

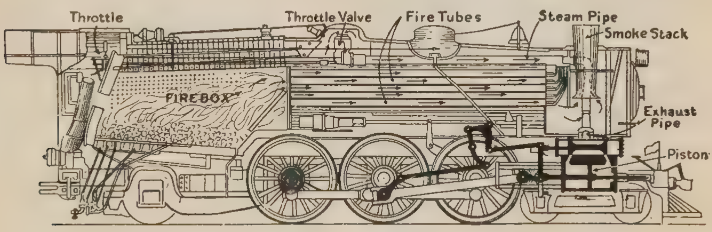


Fig. 368. Sectional View of a Steam Locomotive

The principal parts of the engine of the locomotive are shown by the heavy black lines.

creased, or forced, draft is produced by leading the exhaust pipe from the engine into the smokestack. The rush of steam through the stack carries the burned gases out very rapidly, and fresh air enters the fire box through the draft openings.

Exercise 5. You have probably read about engineers "reversing" their engine to prevent running into another train. What does the engineer do, and why does this slow down the train?

PROBLEM 4: HOW IS THE FORCE OF EXPLODING GAS USED TO RUN AN ENGINE?

All gas engines require an explosive mixture composed of a gas which will burn, and air. In some engines a gas like that employed for lighting purposes may be used. Perhaps

the most common fuel is gasoline. Since gasoline must be changed to a vapor or gas before it is mixed with air to form an explosive mixture, you may properly speak of gasoline engines as gas engines.

Gas engines consist of many parts. The part of the gas engine in which the explosion takes place is nothing more than a cylindrical hole, called the cylinder, bored into a block of iron. Figure 369 shows the top of the cylinder, which is closed by a cap, or *cylinder head.* Three holes open into the upper part of each cylinder. One is the opening for the *spark plug.* The other two openings are called the *intake* and the *exhaust.* The mixture of gas and air enters through the intake, and exploded gas is forced out of the exhaust. These two openings are controlled by valves which open and close automatically at the proper time.

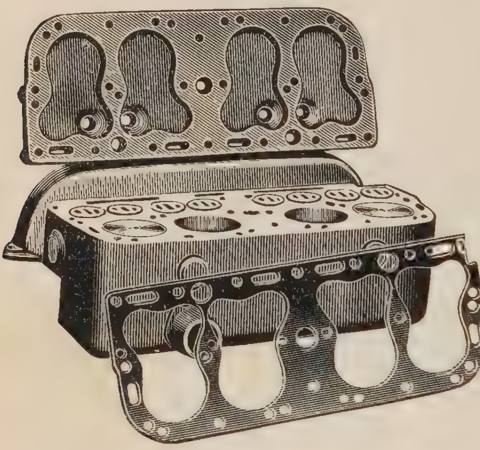


Fig. 369
Cylinder Block of a Four-Cylinder Engine
The spark plug openings are shown in the cylinder head, which is tilted back. The *gasket* in the foreground is placed on top of the cylinder block, and then the cylinder head is screwed down tight.

On the inside of the cylinder is the piston (Figure 361). The piston is connected by a rod to the crank shaft (Figures 361, 371, and 384). At one end of the crank shaft is a large heavy flywheel from which the power is transmitted by a belt, clutch, or series of gears. The other end of the crank shaft is usually fitted with a crank for starting the engine. These parts make up the engine itself.

An explosive mixture does the work. To operate the engine the mixture of gasoline vapor and air must be admitted into the cylinder. To do this, gasoline must first be brought by pipes from the tank to the carburetor (Figure 370). The flow of the gasoline into the float chamber is regulated by a valve attached to the bottom part of the float. From the float chamber the gasoline is sprayed into the mixing chamber, where it is mixed with the proper amount of air.

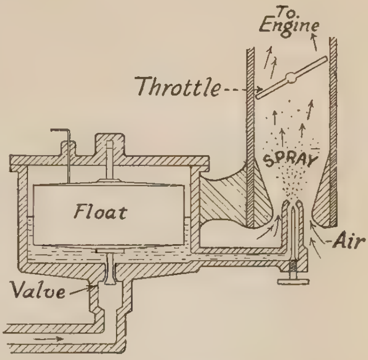


Fig. 370. Sectional View of a Carburetor

Experiment 81: Why must the correct mixture of air and gas be used in a gasoline engine?

(*a*) Obtain a small tin baking-powder can and punch a small hole through the lid. Also punch a small hole in the side of the can near the bottom. Fill the can with illuminating gas by means of a rubber tube leading to the small hole in the side. Stand back at a safe distance and bring a flame near the hole in the lid. What happens? Stand back and observe the flame at the top of the can. As the gas burns at the top, air enters at the bottom. What happens when the correct mixture of gas and air is obtained?

(*b*) If illuminating gas is not available, the experiment may be performed as follows: Warm the can in a flame, remove the lid, and pour in 15 or 20 drops of gasoline. Place the lid on the can and shake the can up and down until the gasoline *vaporizes*. Then bring a flame to the hole in the side. What happens? Repeat the experiment, using a different amount of gasoline until you find the correct mixture to make an explosion.

Exercise 6. A gas engine is difficult to start in cold weather. Why?

Exercise 7. The "choker" on the dashboard of an automobile closes or opens the valve in the air-inlet pipe which leads from the outside air to the carburetor. What is the value of the "choker"?

Exercise 8. The carburetor must be adjusted at different seasons of the year. Why?

The ordinary engine has four cycles. Now let us see how the engine uses the explosive mixture and produces force to do work. First, the mixture must pass from the carburetor

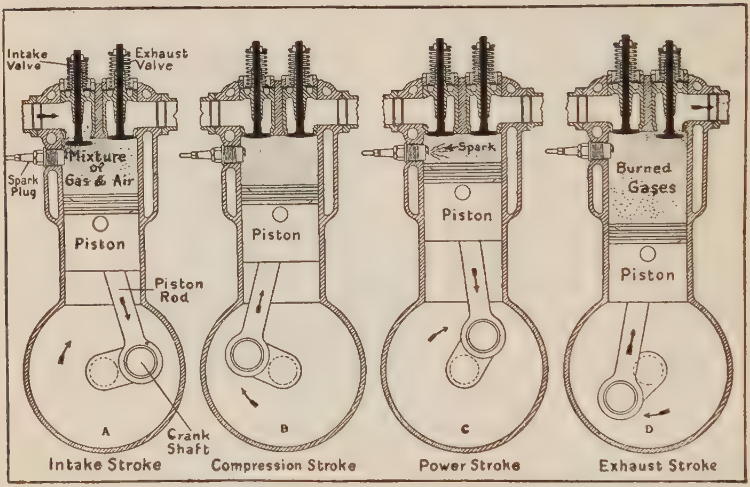


Fig. 371. The Four Cycles of a Gas Engine

The crank shaft rotates in the oval crank case, whch is partly filled with oil, keeping the engine properly lubricated.

to the cylinder. This is accomplished automatically. As the piston moves downward (Figure 371*A*), a partial vacuum is produced in the cylinder. Why? As the intake valve opens, the pressure of the outside air will force air and gasoline vapor from the carburetor into the cylinder. This is called the *intake stroke.*

The cylinder is now filled with an explosive mixture. If the piston is then forced upward, and both intake and exhaust valves are closed, the mixture will be compressed (Figure 371*B*). The compressed mixture will produce a greater force when it is exploded than a mixture which is not compressed. Why? This stroke is called the *compression stroke.*

The piston is now at the top of the cylinder. The electric spark then passes across the gap between the points of the spark plug, igniting the mixture, and an explosion takes place. Both of the valves are closed, so that the full force of the explosion drives the piston downward. This is the explosion, or *power stroke* (Figure 371*C*).

The cylinder is now full of exploded gas. On the upward stroke of the piston, the exhaust valve is opened, and the burned gases are driven out through the exhaust (Figure 371*D*). This is called the *exhaust stroke*.

As soon as the piston starts downward again, the intake valve opens, and a fresh supply of gas and air enters the cylinder. This type is called a *four-cycle* engine. As soon as the four strokes are completed, the engine begins on the next cycle.

Table XIII shows the different strokes and the position of the valves at each stroke.

TABLE XIII. THE FOUR STROKES OF A GAS ENGINE

STROKE	ACTION	DIRECTION OF PISTON	POSITION OF EXHAUST VALVE	POSITION OF INTAKE VALVE
1st stroke	intake	downward	closed	open
2nd stroke	compression	upward	closed	closed
3rd stroke	explosion	downward	closed	closed
4th stroke	exhaust	upward	open	closed

Since the gas engine delivers power only during the explosion stroke, some device is necessary to keep the engine going during the other three strokes. This is accomplished by the flywheel, which is attached to the crank shaft. The flywheel is very heavy, and it takes a great deal of force to put it in motion. (See page 378). As its speed increases, it becomes more and more difficult to stop. The inertia of the flywheel thus keeps the engine in motion during the intervals between the power strokes.

The more cylinders there are, the smoother the engine runs. Automobiles have four, six, eight, or twelve cylinders, and

the explosions are so timed that there is very little interval between the power strokes. In a one-cylinder engine there is one power stroke to every two revolutions of the flywheel. In a four-cylinder engine at any given moment each piston is at a different stroke (Figure 372); consequently there is a power stroke for each one-half revolution of the flywheel. In the six-cylinder engine there is a power stroke for every one-third revolution of the flywheel, and in an eight-cylinder engine a power stroke for every one-quarter revolution of the flywheel. When the engine is going very fast, the explosions take place so quickly that a nearly continuous power is developed.

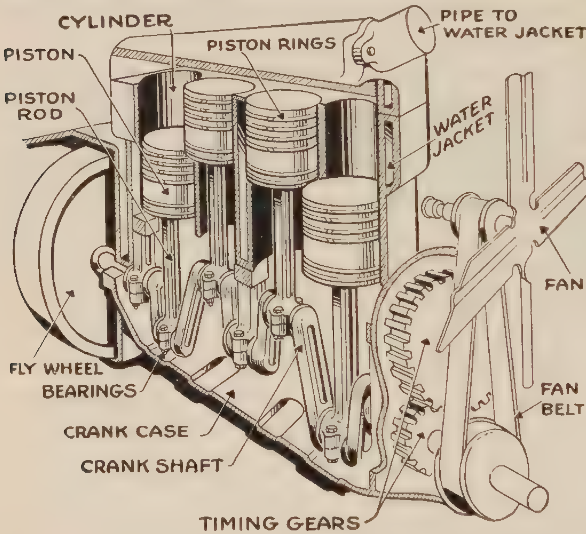


Fig. 372. Sectional View of a Four-Cylinder Gas Engine

Experiment 82: What is the location of each part of the gas engine on an automobile?

Obtain a set of instructions prepared by the company that makes the automobile which you can examine. Read the directions about the location of the gas tank, the carburetor, the cooling system, and the engine itself. Then examine the automobile to locate these different parts: gas tank, pipe to carburetor, carburetor, intake pipe, cylinders, spark plugs, and valves.

An automobile has many systems. In addition to the *power system* there are several other parts necessary in the operation of a gas engine. An *electrical system* is needed to generate electricity and furnish it to the engine at the proper time. All of the moving parts must be well oiled to keep them from wearing out; some kind of *lubrication system* is needed to accomplish this. The tremendous heat produced in the explosion must be carried away to prevent the engine from becoming red-hot. An *air* or *water cooling-system* (Figure 372) takes care of this. In using the engine in automobiles, a *transmission system* is required so that the power of the engine may be transferred to the wheels. In order to keep an automobile or gas engine in good running condition it is essential that the operation of each of these systems be kept at the highest efficiency. This means that each system and its relation to the operation of the car or engine must be thoroughly understood.

Exercise 9. Make a summary of the steps which are necessary to have the gasoline in the tank run a gas engine. Thus:

1. The gasoline must pass to the carburetor, etc.

PROBLEM 5: HOW DOES THE ENGINE RUN AN AUTOMOBILE?

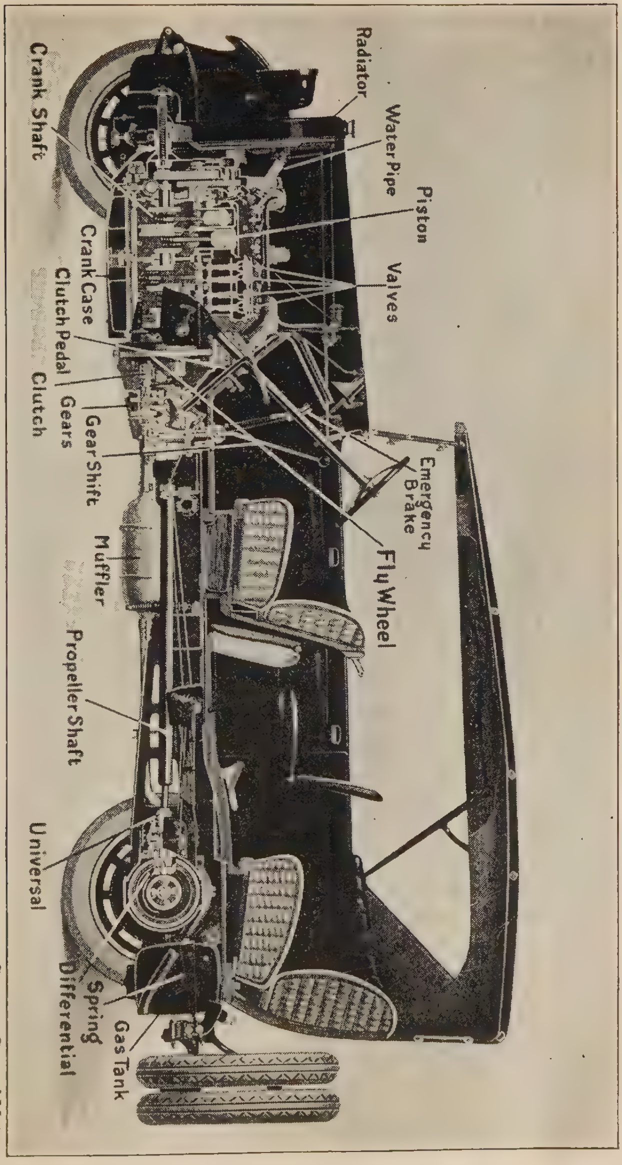
You know that when the engine of an automobile is started, the car is not set in motion. This means that the engine is not yet connected with the rear wheels. If you examine Figure 373, you will see how the engine is connected with and disconnected from the rear wheels. You recall that the gas engine includes a crank shaft and a flywheel, which are made to rotate by the force of exploding gas exerted on the pistons. In order to impart this motion to an automobile a further set of devices is needed. In order of position from the flywheel of the engine to the rear axle of the car these devices are as follows: the clutch, the transmission gears, the propeller shaft, and the differential gears. We shall

now see how each of these functions in making the power of the engine move the car.

The flywheel, as you remember, is attached to the crank shaft of the engine. Connected with the flywheel is the *clutch.* This clutch can be moved backward by the *clutch pedal*, so that it will not come in contact with the flywheel. Thus, when you press your foot on the pedal, you disconnect the clutch from the engine, causing the clutch to stop turning. When the clutch pedal is released, the flywheel sets the clutch in motion.

Back of the clutch is the *gear box* (Figure 373), which contains several gears. When the *gear-shift* is in *neutral*, the gears do not mesh, and no power is transmitted to the *propeller shaft.* When the gears are shifted into low speed, a small gear connected with the clutch drives a large gear connected to the propeller shaft. The small gear revolves more rapidly than the large gear, so that the propeller shaft will turn more slowly than the engine. Why? (See page 336.) When the gears are shifted to second speed, the sizes of the two gears are more nearly alike, and the car will move more rapidly. When the gears are shifted into high speed, in many cars the shaft from the clutch connects directly to the main shaft, and the propeller shaft will turn as fast as the engine. This system of gears is necessary because it requires more power to start the car than it does to keep it moving, and because at different times different degrees of power and speed are needed.

The power is transmitted to the rear wheels by the propeller or driving shaft, which is connected with the main shaft, as shown in Figure 373. Since the propeller shaft turns in a different direction from the rear wheels, another system of gears is necessary to change the direction of the power. This change of direction is accomplished by the *differential*, which is the large round part in the middle of the rear axle. The differential also permits one rear wheel to go faster than the other, which is of course necessary when the car is going around a corner.



Courtesy General Motors

Fig. 373. A Side View of an Automobile

Exercise 10. Trace the transmission of the force of exploding gas from the piston to the rear wheels of an automobile.

Review Exercise on Unit XIII. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit XIII and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT XIII

1. How can a steam engine be used to pump water?

2. Trace back to the sun the energy of steam made by burning coal under a boiler.

3. A locomotive has to exert a greater force to start the train than it does to keep it moving after it is once started. Explain.

4. Large railroad companies have found it necessary to build water-softening plants for producing soft water to be used in the locomotive boilers. Why is this necessary in certain regions and how is the great expense justified? (See page 185.)

5. Why does the puff of a locomotive become more rapid as the engine increases its speed?

6. Make a comparison of the steam engine and the gasoline engine as sources of power for running an automobile.

7. Compare the construction and operation of a steam engine with that of a gasoline engine.

8. A four-cylinder engine produces a more even power than a one-cylinder engine. Why?

9. Why is the radiator of an automobile constructed like a honeycomb?

10. The engine oil should be drained every 500 miles. Why?

11. Why is alcohol used in the radiator in the winter time?

UNIT XIV

GENERATING AND USING ELECTRICITY

Preliminary Exercises

1. Make a list of the uses of electric cells, or "batteries," as they are commonly called.
2. Why cannot cells be used to supply electricity for a city?
3. What kind of cell is used in a flashlight?
4. What kind of cell is used in the automobile?
5. Name as many uses of the electric motor as you can.
6. What is a magnet? How does it work?
7. List as many ways as you can in which one kind of energy may be changed into another kind of energy.
8. Write a paragraph entitled "What Electricity Is." In this paragraph tell all you know about electricity.
9. In what ways have you made use of electricity in the past few days?
10. Make a list of as many electrical devices as you can.

THE STORY OF UNIT XIV

Electricity is one of the most useful forces which nature furnishes to man. By harnessing this force man has come into possession of an unlimited source of energy. Electricity has many uses. It can drive machinery of all sorts, propel vehicles, lift heavy objects, and transmit messages. When it is passed through certain kinds of wire, it is changed into heat and light energy, as occurs in the electric toaster and the electric-light bulb. When it is passed through solutions of certain chemicals, it can decompose them. Use is made of this property to electroplate articles with gold and silver, to free metals from their ores, and to make new chemicals. These are the most important uses of electricity, through which man has changed living conditions so that the humblest home

today may be supplied with conveniences which were beyond the reach of kings a hundred years ago.

Generating or producing electricity is a very simple matter. One simple way to do it is to rub a material like hard rubber with a piece of wool. Another way is by passing a comb through your hair several times. If you then bring the comb near some small pieces of paper, they will be attracted and jump up to it. The comb has become *electrified*. This method of producing electricity was known as far back as 600 B.C. The electric charge on the objects which are rubbed together is known as *static* electricity, for it was formerly thought that electricity does not move, or flow. Because of the method of producing it, it was called *frictional* electricity, and was for more than 2000 years the only kind known. It was thought to have no practical value, and was of interest only to scientists, who regarded it as a rather curious property which some materials possessed.

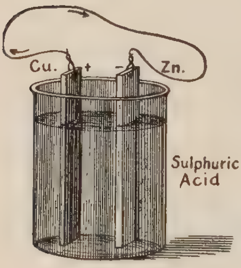


Fig. 374. The Voltaic Cell

Cu is the symbol for copper; Zn is the symbol for zinc. The symbol for sulphuric acid is H_2SO_4.

It was not until 1799 that Alessandro Volta, an Italian scientist, discovered a method of producing a *current of electricity* by inventing the electric *cell*. This cell is very simple and can easily be made by placing a strip of copper and a strip of zinc in a dilute solution of sulphuric acid (Figure 374). If this cell is connected to an electric bell in the manner shown in Figure 375, the bell will ring, showing that an electric current is generated. The electric energy is produced by the chemical action which

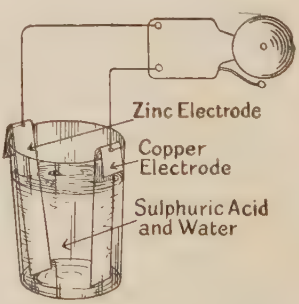


Fig. 375. Simple Cell Connected with an Electric Bell

The zinc and copper strips are called electrodes.

takes place between the zinc and the sulphuric acid. During this chemical action the chemical energy of the zinc and the sulphuric acid is changed into electric energy.

Cells are easily obtained and furnish enough electricity to operate small electric appliances. The type in greatest use at present is called the *dry cell* (Figure 376), although its contents are not actually dry. If you live in a small town or in the country, you will probably find a dry cell inside your telephone. If you trace down the wires which connect with the push-button at the front door, you will probably find that they are connected to an electric cell. If you take apart your flashlight, an electric cell will be found inside. When you press on the starter of your automobile, electricity from a cell sets in motion an electric motor which cranks the engine. The same cell furnishes electricity for the lights and the spark plugs. Radio sets which use vacuum tubes as detectors and amplifiers also operate on cells. Electric cells are very useful, because they can be carried around from place to place with little inconvenience and so made to furnish us with a small current of electricity whenever we need it.

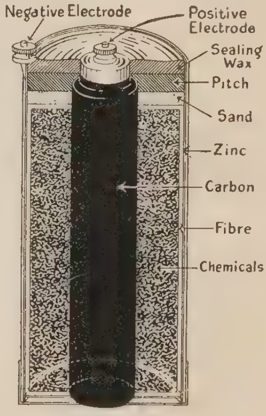


Fig. 376. A Sectional View of a Dry Cell

After you finish studying Problem 1, turn back and examine the different parts of this cell.

Since man first recognized the wonderful source of power which electricity gave to him, he has been constantly experimenting to find new methods of generating and using it. He discovered very early that the cell did not furnish sufficient electricity for his uses. Until 1831, however, the cell was the only source of current electricity. In that year, Faraday, a famous English scientist, discovered that an electric current could be *generated* by moving a coil of wire between the poles

of a horseshoe magnet (Figure 377). After about forty years of experimentation this method resulted in the perfection of a machine which would produce a heavy current of electricity. This machine, which is called the *dynamo*, may be run by a steam engine, gas engine, or water-wheel. Wires connected to the machine carry an electric current away from it.

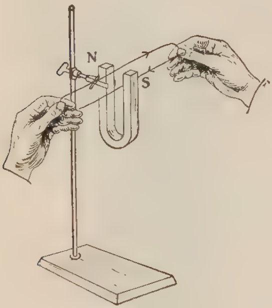


Fig. 377. Generating an Electric Current

If the loop of wire is revolved either backward or forward, a current of electricity is generated in it.

With a powerful source of electric energy, such as the dynamo supplied, man's understanding and use of electricity increased rapidly. One of the many electrical devices invented was the electric *motor*. This is used to run fans, pumps, automobiles, and machinery of all sorts. The motor differs but little from the dynamo in construction; in fact, some dynamos can be used as motors. The main difference between them is in their operation. The motor is connected by wires with the dynamo or cell, and the electricity which flows through the motor causes the motor to turn.

PROBLEM 1: HOW ARE CELLS USED AS A SOURCE OF ELECTRICITY?

A complete circuit is necessary. The easiest way to understand how a simple cell is used is to construct one and connect it to some electrical device.

Experiment 83: How is a simple cell constructed and connected so as to furnish an electric current?

(*a*) Obtain a glass tumbler, a small strip of zinc, and a strip of copper. Make a small hole in one end of each strip, so that a wire may be attached. Bend the end with the hole so that it will hang on the rim of the tumbler (Figure 375). Make a solution of sul-

phuric acid, using one part of acid to ten parts of water. (Always pour the acid into the water.) Pour this mixture into the tumbler.

(*b*) Place the zinc and copper strips in the solution and connect one of them by a wire to one *binding post* of an electric bell. Does the bell ring? Now connect the other strip to the other binding post of the bell. Does the bell ring?

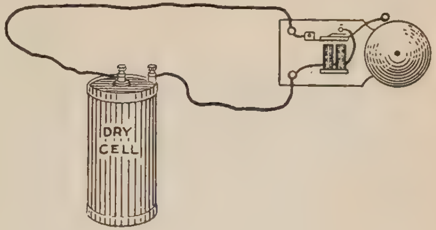


Fig. 378. A Complete Circuit

The bell will ring as long as the circuit is complete.

You see from Experiment 83 that both the zinc and copper strips have to be connected to the bell before it will ring. In all electric circuits a wire must be connected from the cell to the device which is being operated, and then another wire must be connected back to the other strip in the cell. Before electricity will flow from a cell, there must always be a complete *electric circuit* (Figure 378). Copper wire is generally used for this purpose because it is a good conductor of electricity.

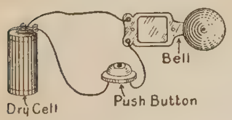


Fig. 379. An Electric Circuit Containing a Circuit-Breaker

The circuit is made and broken by the push-button. (See Figure 380.)

In operating an electric bell, a *push-button* is placed in the circuit (Figure 379). Figure 380 shows the construction of a push-button. A flat strip of brass is fastened at the bottom, and one wire from the cell is attached to it. At the top is a piece of brass spring which is connected to the wire leading to the bell. When the push-button is not pressed down, the current cannot pass, because the circuit is *broken*. When the push-button is pressed down, the two pieces of brass are brought together and the circuit is *made;* therefore the current can pass. A device, like the push-button,

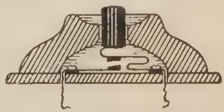


Fig. 380. A Side View of a Push-Button

When the button is pushed downwards, the circuit is completed.

which can "make" or "break" the circuit is called a *circuit-breaker*. *Switches* (Figures 381, 382, and 383), which are used to turn on or off electric lights or motors, are circuit-breakers. When connecting any electrical devices to a cell or other source of electricity, always check over your connections to be sure you have a complete circuit.

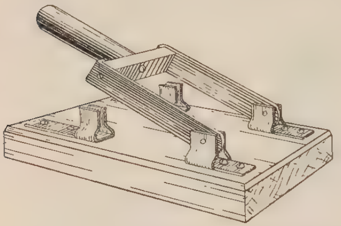


Fig. 381. A Double Throw-Switch
This type of switch is commonly used where a strong current passes through the circuit.

You have probably heard about *short-circuits*. Let us see what this term means. Electricity always travels by the shortest possible path, and, if two wires should happen to touch, as shown in Figure 384, only a small part of the current would pass through the bell, most of the current taking the short cut back to the cell. This is a short-circuit. One method of guarding against short circuits is to use *insulated* wire. Materials like cotton, wool, silk, and rubber are *non-conductors* of electricity; that is, electricity will not travel through them. If the wires are wrapped with any of the above materials, the wires are insulated, and the insulators may touch each other without any danger of a short-circuit unless too great a current is sent through them. Short-circuiting will wear out a cell rapidly, and may cause fires. Therefore, when you are making connections for electrical devices, you should always use insulated wires or keep the wires far apart.

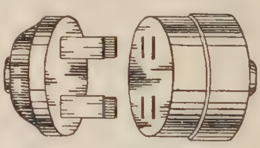


Fig. 382. Plug and Receptacle
This is a very common attachment for electric irons, toasters, and fans.

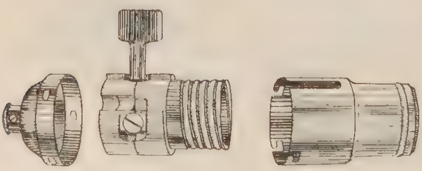


Fig. 383. A Key Socket
This is the common electric-light socket.

How a simple cell is made. In the last experiment you constructed a simple cell, using zinc and copper strips and sulphuric acid. The strips in a cell are called *electrodes*, and the liquid in which they are placed is called the *electrolyte*. In other words, the simple cell consists of a zinc electrode and a copper electrode placed in the electrolyte, sulphuric acid. Certain materials must be used as electrodes; some cannot be used as electrolytes, as Experiment 84 shows.

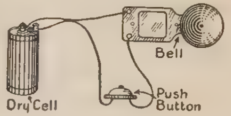


Fig. 384. A Short-Circuit Insulation would prevent a short-circuit here.

Experiment 84: What materials are necessary in making a cell?

(*a*) Construct a cell as in Experiment 83. What evidence of chemical action, such as the production of heat or bubbles of gas?

(*b*) Obtain two copper strips and place them in a solution of sulphuric acid. Do you note any evidence of chemical action? Connect with a bell. Does it ring?

(*c*) Obtain a dry zinc and dry copper electrode and place them in a solution of sugar and water. Do you note any evidence of chemical action? Connect with a bell. Does it ring?

In order for electric energy to be produced by a cell, two different kinds of materials must be used for the electrodes. These materials must be conductors of electricity. Furthermore, the electrolyte must be such that it will act chemically upon one of the electrodes. If the cell which you constructed is left connected for some time, you will see that the zinc is gradually dissolved by the acid. The copper electrode does not act with the sulphuric acid. It is therefore called the inactive electrode. Chemical energy is changed into electric energy by the action of the zinc with the sulphuric acid. There are many different types of cells, but all are constructed on the same principle as the simple cell.

Exercise 1. Why is a dry cell more practical than the simple cell?

Exercise 2. Explain the meaning of the following terms: electric circuit, short-circuit, circuit-breaker.

Exercise 3. Would a cell work using two zinc electrodes in a solution of sulphuric acid? Try it. Explain your results

PROBLEM 2: HOW IS ELECTRICITY MEASURED?

The flow of electricity through a wire is very similar to the flow of water through a pipe. In order to use cells properly it is first necessary to have an idea of the nature of an electric current. You remember (page 126) that in a gravity system the water flows through pipes because of the pressure of the water in the reservoir. This pressure is measured in pounds per square inch. The quantity of water flowing through the pipes is measured in gallons per minute. The number of gallons which will flow through a pipe depends upon three things: (1) the pressure of the water in the reservoir; (2) the diameter of the pipe; and (3) the resistance which the surface of the pipe offers to the flow of the water.

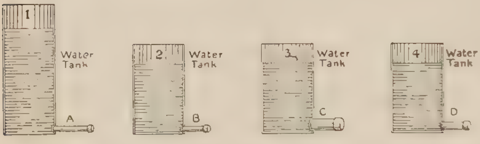


Fig. 385. Diagram for Exercises 4, 5, and 6

Exercise 4. When the plugs are unscrewed, will water flow faster through Pipe A or Pipe B (Figure 385)? Explain.

Exercise 5. Water will flow faster through Pipe C than through Pipe D (Figure 385). Why is this true?

Exercise 6. Select the tank which will furnish the greatest pressure; select the pipe with the least resistance.

In an electric cell a greater electrical pressure is produced on the electrode which acts chemically with the electrolyte than upon the inactive electrode. Thus, in the simple cell the electrical pressure built up on the zinc electrode causes a current to flow through the wire to the copper electrode. This electrical pressure is commonly called *electromotive force* (E.M.F.), and the unit which is used to measure it is called the *volt*. The electrical pressure of a simple cell such as you constructed is approximately one volt When the electrodes of a cell are connected by a wire, the wire offers a resistance to the passage of electricity through it. The unit used to measure this electrical resistance is the *ohm*. The amount of current

flowing through the wire per second is measured by the *ampere.* A comparison of the units used in a water-supply system and those used in measuring electric current is given below.

	WATER	ELECTRICITY
FLOW	Gallons per second	Amperes
PRESSURE	Pounds per square inch	Volts
RESISTANCE	Pounds per square inch	Ohms

If the water pressure in the pipes is increased by raising the height of water in the reservoir or by operating the pumps more rapidly, the amount of water flowing through the pipes will also be increased, because there will be a greater force to overcome the resistance which the pipes offer. In the same manner, if the electrical pressure is increased, the amount of current will increase. If a longer pipe or a smaller pipe is used, the resistance will be greater, and the amount of water flowing through it will decrease. If a longer wire or a smaller wire is used, the resistance to the current will increase, and consequently the amount of current passing through the wire will decrease. This relation of the electrical pressure, the current strength, and the resistance is expressed in the following way:

$$\text{current strength} = \frac{\text{electromotive force}}{\text{resistance}},$$

or in terms of the units of measurement,

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}}.$$

This is called *Ohm's Law,* in honor of the man who discovered it. You can easily see how this law may be applied. For example, suppose that the electromotive force of a cell is one volt and that it is connected to a bell which has a resistance of four ohms. How much current will flow through the wire? Since the number of amperes equals the volts divided by the ohms, if you divide one by four you find that one-fourth of an ampere flows through the wire. What would be the current strength if the electromotive force, or *voltage,* were doubled?

Exercise 7. A cell which has an electromotive force of one volt is connected to a small motor. The current strength is one-fourth ampere. What is the resistance of the motor and the wire used to connect it?

Exercise 8. An electric-light bulb has a resistance of 220 ohms. When connected to the lighting circuit, one-half ampere of electricity passes through it. What is the voltage of the lighting circuit?

Exercise 9. State two ways in which the current strength in a circuit can be increased.

PROBLEM 3: HOW SHOULD CELLS BE CONNECTED?

If you wish to operate any electrical device by means of cells, the proper E.M.F. and the proper current flow must be obtained. This may be done by using the correct number of cells and the proper kind and length of wire for the circuit, by making good connections, and by using the correct "hook-up."

Experiment 85: What kind of wire will secure the largest possible current?

(*a*) Obtain two pieces of copper wire of equal length, one about No. 30 to No. 36 and one about No. 18 or No. 20. Connect each one separately to a simple cell or a dry cell and measure the current strength with a compass. This can be done by placing a compass on the table and turning it so that the needle points north and south, as shown by the markings on the dial. Now connect the electrodes with the larger of the two copper wires. Bring the wire over the compass, as shown in Figure 386. The compass needle changes position, and the strength of the current is indicated by the number of degrees the needle shifts. Now use the wire of small diameter and repeat the test. Compare the results obtained.

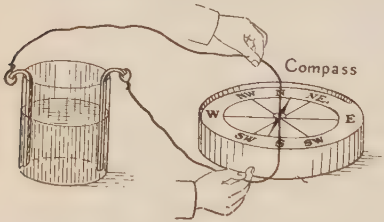


Fig. 386. Apparatus for Experiment 85

(*b*) Obtain a piece of copper wire and a piece of iron or german-silver wire of exactly the same diameter and length. Connect as in (*a*) and measure the current. Compare results.

(*c*) Obtain two pieces of iron wire of the same diameter, but one twice as long as the other. Connect as in (*a*), measure the current, and compare the results.

What kind, size, and length of wire would you use to cut down the resistance?

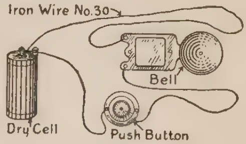


Fig. 387. Diagram for Exercise 10

No. 30 wire means that if the wire is wound on a pencil, there will be 30 turns to an inch.

The method of attaching the wire to the binding posts, or *terminals*, of the cell and other instruments is also of great importance in cutting down the resistance. The ends of the wire should always be well scraped and should be attached firmly to the binding post. The best connections are made by *soldering*. If bare wires are used, care must be taken that they do not touch, for, as you recall, a short-circuit will be formed if they do.

Exercise 10. What changes would you make in the electric circuit in Figure 387 if you wanted the bell to ring as loudly as possible?

Proper combinations of cells should be used. For some uses, such as in radio, it is necessary to hook-up two or more cells, that is, a *battery* of cells. There are two common methods of connecting cells, in *series* and in *parallel*. Cells are connected in series as shown in Figure 388.

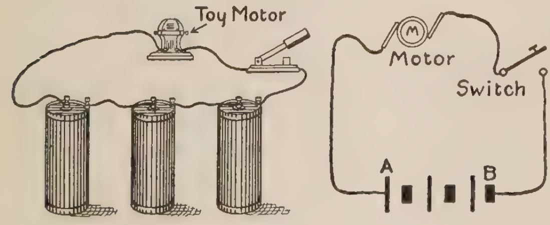


Fig. 388. Three Cells Connected in Series

The diagram at the right shows the customary signs used by the electrician to indicate the different devices.

Note that the negative electrode (the zinc) of one cell is connected to the positive electrode (the carbon) of the second cell (see Figure 376), and the negative electrode of the

second cell is connected to the positive electrode of the third cell. From the other two electrodes, marked (A) and (B), wires lead to the device to be operated. When cells are connected in series, the E.M.F. is increased. For example, the E.M.F. of one dry cell is 1.5 volts. Two dry cells connected in series have an E.M.F. of 3 volts, and three dry cells connected in series have an E.M.F. of 4.5 volts. In operating electric bells, telegraphs, and motors where high voltage is required, a series connection usually gives the best results.

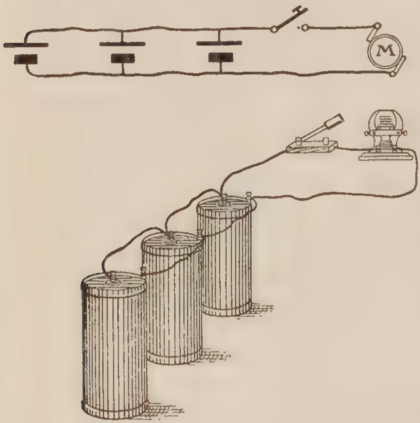


Fig. 389. Three Cells Connected in Parallel

What is the difference between connecting cells in parallel and in series? (See Figure 388.)

Cells are connected in parallel as shown in Figure 389. You will observe that the positive electrodes of all cells are connected together, and also that the negative electrodes are joined. In this arrangement the total E.M.F. is the same as the voltage of one cell. This arrangement of cells is used when a high voltage is not required and when a continuous current is needed over a long period of time. Its chief use is in connecting cells for lighting vacuum tubes in radio sets. Thus, when you have a 1.5 volt radio tube, it is more economical to light it with two cells connected in parallel than to use two single cells, one after another.

Experiment 86: To discover the better method of connecting cells to a toy motor.

Obtain two dry cells and a small electric motor. Connect the cells in series with the motor and observe how fast it goes. Repeat,

connecting the cells in parallel. Which one of the two connections makes the motor run the faster?

Exercise 11. Dry cells have an E.M.F. of 1.5 volts. Make a drawing showing how you would connect two cells to a 1.5-volt vacuum tube, such as is used in radio. (More than 1.5 volts forces so much current through the filament of the tube that the filament will melt, or "burn out" in a short time.)

PROBLEM 4: HOW DOES A STORAGE CELL FURNISH AN ELECTRIC CURRENT?

A storage cell is made up of two electrodes of different materials and an electrolyte, as is the simple cell. When the ordinary cell is used for a long time, the negative electrode is used up, and the cell becomes worthless. The storage cell also becomes inactive, or "dead," after it is used for a long time, but its activity may be restored by *charging*.

Experiment 87: How is a storage cell constructed and charged?

(*a*) Take two 1-by-4-inch lead plates. Make a solution of sulphuric acid, using one part of acid to eight parts of water. Pour this solution into a tumbler. Place the lead plates in the solution so that they do not touch each other.

(*b*) Attach the lead plates to an electric bell (Figure 375). Does the bell ring? Explain.

(*c*) Connect three dry cells in series to the lead plates and allow a current to pass through for three or four minutes (Figure 390). Note the bubbles which collect on one plate and the change in color on the other plate.

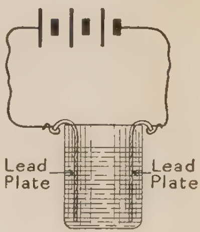


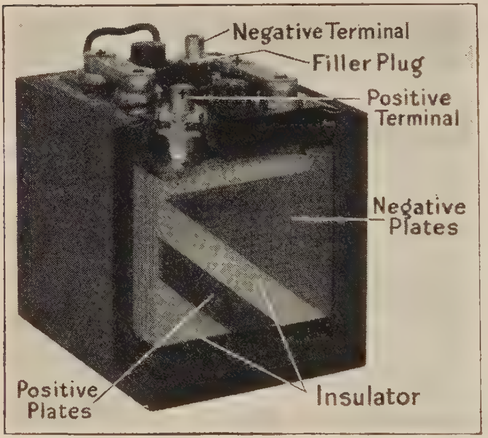
Fig. 390. Demonstration Storage Cell

(*d*) Disconnect the dry cells and connect the lead plates to the electric bell. Result? Leave the bell connected until it stops ringing. Examine the lead plates and note any change in color.

(*e*) After the bell stops ringing, pass a current through the cell as in (*c*), and then connect the bell again. Results?

When the two lead plates are first put in the acid, no current is obtained, because they are both made of the same material. When the current is passed through, one electrode turns

brown, caused by a chemical change on the surface. The other plate remains as lead. You now have a cell with different kinds of electrodes, because the charge has changed the material of one. The electric energy which was passed into the cell has been changed to chemical energy. When the cell is discharging, the sulphuric acid acts upon the plates chemically and changes them into the same materials on the surface. No current can now flow, because the electrodes are composed of the same materials. When a current is passed through again, the cells are restored to their original condition, or recharged.



Courtesy Prest-O-Lite Co

Fig. 391. Sectional View of a Storage Battery

Note the large size of the plates. This cuts down the internal resistance of the cell and also allows the storage of a large amount of chemical energy.

In the commercial storage battery several cells are used, the number depending upon the voltage required. The voltage of a storage cell is about two volts. For a six-volt battery three cells are connected in series. The materials used in batteries are usually lead for the negative electrodes, *lead peroxide* for the positive electrodes, and sulphuric acid for the electrolyte. These materials which compose the electrodes are pressed into frames, or *grids*. Each cell contains several positive and several negative grids or plates. Perforated hard-rubber plates or other non-conductors keep the plates from touching so they will not become short-circuited. Positive plates of the cells are connected to positive, and negative plates to negative, as shown in Figure 391.

Unfortunately no "fool-proof" storage battery has thus far been constructed. Storage cells are easily ruined if they do not have the proper care. The water in the cell evaporates, which makes it necessary to add water occasionally. Distilled water is always used for this purpose, since it contains no minerals which might injure the cells. The solution should never be below the top of the plates. The condition of the cell can be determined by means of an *hydrometer* (Figures 392 and 393). Each hydrometer has a scale upon which are printed numbers from 1100 to 1300. A cell, to be fully charged, must register from 1270 to 1300. If it falls below 1150, it is practically discharged and should be recharged at once. If the cells test differently, they should be taken to a competent battery expert, because they are short-circuited, or something else is wrong. If for any reason the battery is not working properly, never pour acid into it or try to fix it yourself. Take it to a battery station.

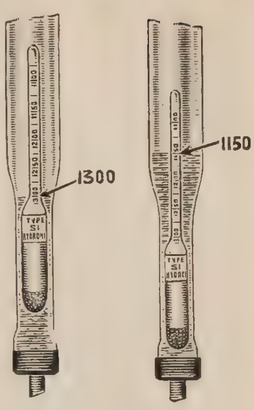


Fig. 392. Hydrometer Readings of a Charged and a Discharged Cell

Which reading is that of the charged cell?

Fig. 393. Testing a Storage Battery

The filler plug is removed, and the hydrometer is inserted into the cell. Squeezing the bulb and then releasing it will cause some of the electrolyte to rise into the hydrometer. Why?

Exercise 12. Explain how a storage cell differs in its construction and its operation from a simple cell.

One often hears the statement, "a storage cell stores electricity." Is this true? Explain.

PROBLEM 5: HOW DOES A DYNAMO GENERATE AN ELECTRIC CURRENT?

Magnets can be used to produce electricity. In order to understand how a dynamo generates an electric current, it is first necessary to examine the force exerted by magnets.

Experiment 88: What is the nature of the force exerted by magnets?

(*a*) Place either a bar magnet or horseshoe magnet in a pile of iron filings and then pick it up. Do you find the same amount of filings clinging to all parts of the magnet? The points where the magnetism appears to be concentrated are called *poles*.

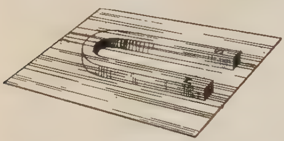


Fig. 394. Apparatus for Experiment 88, part (*b*)

(*b*) Secure a thin piece of cardboard or a glass plate and some fine iron filings. Place the cardboard or glass plate over a horseshoe magnet, as shown in Figure 394. Sprinkle some iron filings on the glass plate, gently tapping the plate as you do so. Make a drawing showing the arrangement of the filings.

(*c*) Wrap 10 turns of insulated wire around a large iron nail. Connect the wire to a cell as shown in Figure 395. Bring the end of the nail near several smaller nails and note that the latter are drawn over to the magnetized nail. How many nails will it hold up? Disconnect one wire from the cell. What effect does this have upon the magnet?

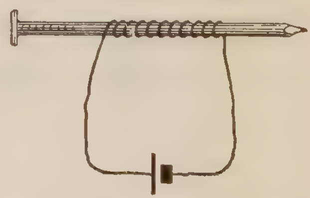


Fig. 395. Apparatus for Experiment 88, part (*c*)

From the experiment you see that there are two kinds of magnets. The bar and the horseshoe magnets, made of steel, retain their magnetism and are therefore called *permanent* magnets. When a coil of wire through which an electric current is passing is wound around an iron nail, you have an *electromagnet*. This retains its magnetism only so long as the current is passing through it. It is a *temporary* magnet. The experiment also shows that invisible rays extend between the poles of a magnet, which affect pieces of iron placed in their paths. These are *magnetic rays* or *lines of force*.

Whenever a coil of wire is moved between the poles of a magnet, the wire must cut through the magnetic lines of force which extend from one pole to the other.

Experiment 89: What effect do the lines of force have upon a coil of wire which cuts through them?

(*a*) Wrap a large nail with about 40 turns of No. 24 or No. 22 insulated copper wire, leaving about one-half inch of the nail exposed at each end.

(*b*) Connect the two loose ends of the wire and hold the wire over the compass as shown in Figure 386, page 398.

(*c*) Clamp the nail so that it cannot move (Figure 396), and bring a horseshoe magnet toward it so that the poles pass over the coil which is wound around the nail. Observe that the needle of the compass moves either to the right or left as the magnet approaches. When the magnet is not in motion, there is no movement of the compass needle.

(*d*) Pull the magnet away from the coil. Note that the compass needle turns, but this time in the opposite direction to that of the first time.

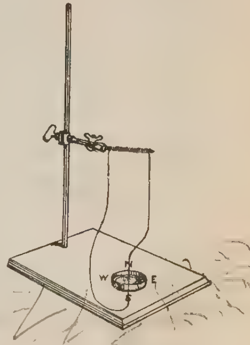
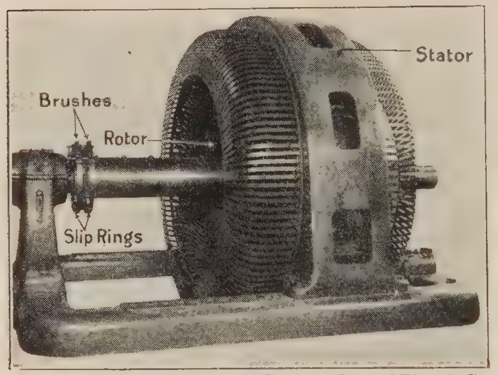


Fig. 396. Apparatus for Experiment 89

When the magnetic lines of force between the poles of the horseshoe magnet are forced over the coil of wire, a current of electricity is produced in the coil. This was shown by the movement of the compass needle, which detects the presence of electrical currents. Furthermore, the direction of the current depends upon the direction in which the lines of force cut the coil. This was shown by the compass needle, which turned one way when the magnet was brought to the coil and in the other direction when it was moved away. An electric current is thus produced in a coil of wire when the lines of force between the poles of a magnet cut through the coil. It makes no difference whether the magnet or the coil is moved. Whenever lines of force are cut by a conductor, they produce a current of electricity.

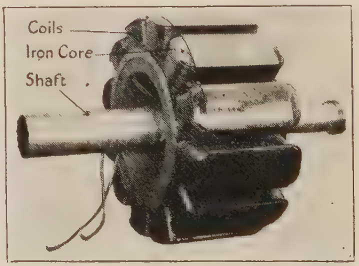
A dynamo has four essential parts. There are four essential parts to a dynamo (Figure 397): (1) *field-magnets*, or *stator*, (2) *armature*, or *rotor*, (3) *slip-rings*, and (4) *brushes*. The field magnets are made of soft iron, and are wrapped with insulated copper wire through which the current passes, making it an electromagnet. The armature consists of a coil of insulated wire wrapped on an iron core, and rotates between the poles of the field magnet (Figure 398). The two ends of the copper wire in the armature are connected to the slip-rings, which turn with the armature. The brushes slide on the slip-rings and conduct the electricity to the outside circuit. The shaft of the armature is connected to a steam engine, water turbine, or other source of power, which causes the armature to rotate. In this dynamo the field-magnets are so arranged that the current set up in the coils changes direction many times each second. This is called an *alternating* current; that is, the current travels first in one direction and then in the other. The slip-rings bring this current to the brushes, which connect



Courtesy General Electric Co.

Fig. 397. An Alternating-Current Dynamo

The rotor of this dynamo is shown separately in Figure 398.



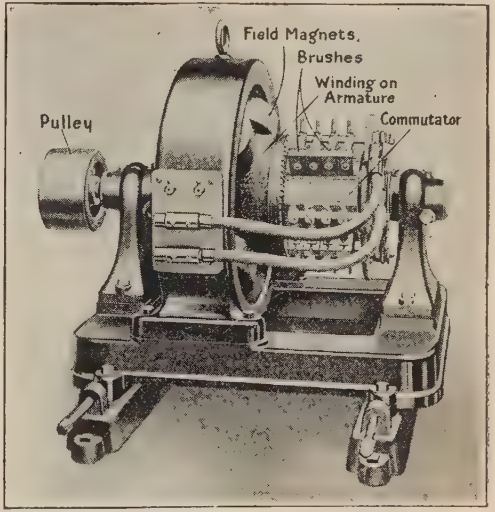
Courtesy General Electric Co.

Fig. 398. Rotor of a Dynamo

This rotor is forced to rotate inside the stator by steam, gas, or water power.

to the outside circuit. Dynamos furnish much higher voltage than cells. The usual voltage is 110 or 220. The ordinary house-lighting circuit requires 110 volts. Dynamos constructed to operate lighting circuits are run at such speed that the current changes direction 60 times a second. This is called a 60-*cycle* alternating current.

Exercise 13. Explain as fully as you can how an electric current is produced in a dynamo.



Courtesy Holtzer-Cabot Co.

Fig. 399. A Direct-Current Dynamo

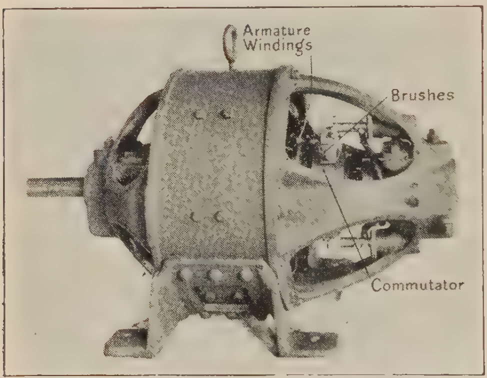
The essential difference between a direct-current dynamo and an alternating-current dynamo is in the method of taking the current from the rotor. The commutator changes the alternating current to a direct current.

Some dynamos are constructed so as to furnish a *direct* current; that is, the current always moves in the same direction. In this type of dynamo (Figure 399) a *commutator* is used in place of the slip-rings. The commutator is connected to the coils of the armature in such a way that when the direction of the current changes in the coils, the brushes will touch only the segments of the commutator through which the current is always traveling in the same direction. Thus the brushes carry off a direct current to the outside circuit.

The direct-current dynamo is commonly used to charge automobile storage batteries, because the current must always enter the battery from the same direction in order to produce a different chemical change on the two electrodes.

PROBLEM 6: HOW DOES AN ELECTRIC MOTOR OPERATE?

An electric motor (Figure 400) is very similar in construction to an electric dynamo; in fact, it can be made to serve either as a motor or dynamo. The action of the motor, however, is just opposite to the action of the dynamo. The dynamo produces electricity; the motor uses electricity to do work. A simple motor, which will show how an electric motor operates, is very easily constructed.



Courtesy Westinghouse Co.

Fig. 400. A Direct-Current Motor

This is a 10 horse-power motor. Its actual size is about 20 inches high and 25 inches long.

Experiment 90: How may a simple motor be constructed?

(*a*) For the armature, obtain a straight-sided cork about two inches long and three-quarters inch in diameter. Cut or notch it on two sides and wind it with about 20 turns of No. 22 or No. 24 insulated wire (Figure 401). Then cut two small pieces of No. 18 bare copper wire about an inch long. Push them into the cork at right angles to the winding. Fasten the free ends of the wire on the cork, one to each of the wires in the cork. Place a horseshoe magnet over the armature. Connect a copper wire to each electrode of a dry cell. Bare the ends of the wire and hold them in such a manner that they will touch the wires to which the coil is attached, when the faces of the coil on the armature

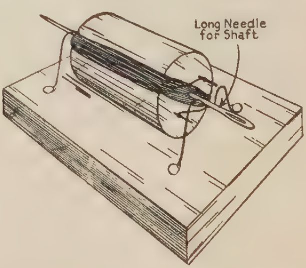


Fig. 401. Rotor of a Simple Motor

are up and down (Figure 402). (If the armature does not turn, connect up two more dry cells, or increase the number of magnets.)

(*b*) Reverse the direction of the current through the motor by reversing the wires. What effect does this have upon the directions in which the armature rotates?

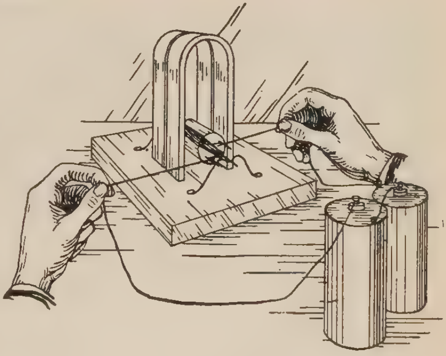


Fig. 402. Construction of Simple Motor

The armature moves around in the motor because of the magnetic forces which are acting upon it. There are two magnetic fields: that of the field magnets and that around the coils of wire on the armature. If the current is brought into the armature when the coils of the armature are in a certain position, the two magnetic fields oppose each other, and the result of the magnetic forces is to cause the armature to turn. When the direction of the current is changed, the motor runs in the opposite direction.

The speed of an electric motor is regulated by putting greater or less resistance into the circuit to change the current strength. (See page 397). A device for accomplishing this is called a *rheostat.* If you have a small electric motor, you can construct a rheostat to regulate its speed.

Experiment 91: How can a rheostat for a small motor be constructed?

(*a*) Obtain some No. 24 or No. 30 iron or german-silver wire. Wind about 30 turns around a pencil. Now connect one end of the coil to a dry cell. Connect the other electrode of the cell to the motor. Attach a copper wire to the other binding post of the motor and touch the free end of the wire to the free end of the coil. Does the motor run? If it does, it will be necessary to add more turns to the coil until finally the motor will not run. Now obtain a wooden

block to serve as a base, a strip of copper or brass for the rheostat arm, and assemble as shown in Figure 403.

Fasten one free end of the whole coil to a tack at the left of the board. Then divide the coil so that equal portions of the coil will be between the other tacks on the board. If the arm of the rheostat is placed on the tack at the left, none of the coil will be in the circuit. If the arm is placed on the second tack on the left, the part of the coil between the two tacks will be in the circuit. Thus, the farther to the right the arm is moved, the greater the length of wire which will be in the circuit and the greater the resistance.

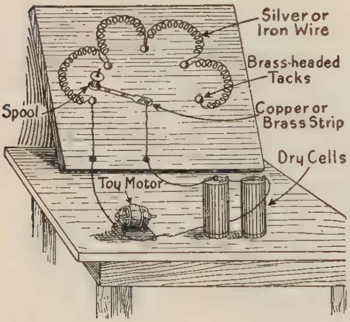


Fig. 403. A Simple Rheostat

If 60 turns of wire are necessary to make the coil, there will be about 15 turns of wire between tacks.

In starting a motor, all of the resistance should be in, otherwise a full current may cause the insulation to burn off and short-circuit the coils. Then the switch arm is moved slowly forward, cutting out more and more resistance as the motor gains in speed.

Exercise 14. Explain the difference in the operation of the motor and the dynamo.

PROBLEM 7: HOW CAN ELECTRICITY BE USED FOR ELECTROPLATING?

One of the many uses of electricity is that of plating objects with gold, silver, copper, nickel, or other metals. If you examine some of the silverware at home, you may find it stamped with the words "Silver-plated." Practically all silver dishes or other silver objects which are not stamped "Sterling Silver" are plated.

Experiment 92: How are objects electroplated?

(*a*) Make a solution of copper sulphate and water and pour it into a glass tumbler or beaker. Obtain a clean silver dime and make

a little stirrup of copper wire so that the dime can be suspended in the solution. Also obtain a strip of copper about four inches long and a half-inch wide. Connect the coin to the negative electrode of a dry cell (see page 399) and the copper strip to the positive electrode of the same cell.

(*b*) Place the silver coin and the copper strip in the solution for a few minutes (Figure 404). Remove the coin. Result?

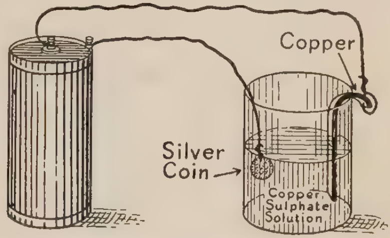


Fig. 404. Electroplating Apparatus

Be sure to connect the silver coin to the negative electrode.

Electricity has the power to decompose or break up materials like copper sulphate when they are in solution. Copper from the solution is deposited on the coin. At the same time some of the copper which composes the copper strip goes into solution and takes the place of the copper which was deposited. In this way the strength of the solution is maintained.

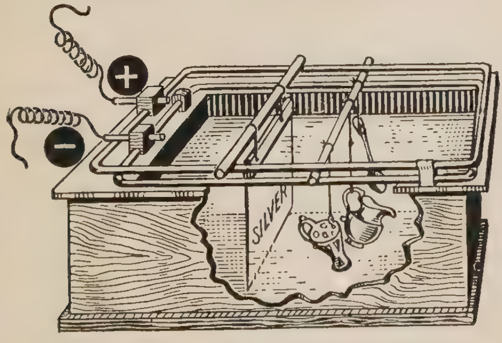


Fig. 405. Plating Articles with Silver

The bar from which the articles to be plated are suspended is not in contact with the positive electrode, although this view makes it appear so.

In plating with silver or other materials the same method is used. A compound of silver which can be decomposed by electricity is used as an electrolyte, and the article to be plated is connected to the negative electrode of the source of current. A bar of pure silver is connected to the positive electrode of the cell (Figure 405).

Exercise 15. How is electroplating done?

Review Exercise on Unit XIV. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit XIV and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT XIV

1. Make a diagram showing the connections of a battery of dry cells which will furnish 15 volts.

2. By means of a drawing, show how an electric bell in the front part of the house and one in the kitchen can be operated by one push-button at the front door.

3. Can glass be used as an electrode? Why?

4. Copper wires are generally wrapped with cotton or silk. Why?

5. The tops of dry cells are covered with tar or pitch. Why?

6. Cells finally "wear out" so that they will no longer produce an electric current. How do you account for this?

7. Why will radio tubes burn out if they are connected to the "B" battery?

8. Why is a cardboard cover put on dry cells?

9. Make a list of as many materials as you can which will conduct electricity; which will not conduct electricity.

10. Why does an electric motor run faster if more current is sent through it?

11. Compare the advantages and disadvantages of the dynamo and the cell as sources of electricity.

12. In what different ways can the power of a motor be transmitted to run machinery?

13. How is the speed of an electric fan controlled?

14. Make a drawing to show your idea of how a water turbine is used to run a dynamo.

15. What are three different ways by which the speed of a motor may be changed?

16. Visit the electric-light plant or other power plant in your city. Report to the class on your trip.

17. What is the voltage of your automobile battery? How can you tell?

18. Get an old storage battery and examine its construction.

UNIT XV

LIGHTING OUR BUILDINGS AND STREETS

Preliminary Exercises

1. Name as many ways of lighting buildings as you can.
2. Explain why light comes from a fire. How does an electric-light bulb produce light?
3. How did primitive people light their buildings?
4. In writing it is customary to have light come from the left. Why?
5. If you were asked whether or not a certain room is well lighted, what points would you consider in giving your answer?
6. What advantages has electric light over other kinds?
7. Why are mantles used with gas lights?

THE STORY OF UNIT XV

Proper lighting of our buildings and streets makes them not only more attractive but also more healthful places in which to live. When man began to use glass for windows, which allowed the sunshine to enter buildings during the day, and to invent devices to light his buildings and streets at night, he greatly changed his way of living. Imagine what the inside of buildings would be without glass and artificial methods of lighting!

The earliest methods of artificial lighting were the open fires outside the shelters of primitive people. As you have learned (see page 259), the open fire was also used inside the shelters. Later, animal fat was burned in open vessels. Wicks of various kinds were placed in the fat and ignited, providing a poor light which smoked and gave off unpleasant odors. Sometimes the crude wicks were simply stuck into a piece of animal fat, such as whale blubber or candle-fish fat. In time man learned to

make candles of the animal fat and also to make a lamp by putting oil in a vessel and placing a crude wick in the oil (Figure 406). Hundreds of years later candles were made of paraffin. Some early lighting devices are shown in Figure 407. Figure 409 illustrates various forms of present-day gas and electric lights. The first practical use of gas for lighting a building was made by an Englishman, Murdock, in 1792. With the discovery of ways to separate crude petroleum into different fuels, kerosene came into use in lamps about 1860. In 1879 Edison gave us the first electric bulb, or *incandescent light* (Figure 408), though an electric arc lamp which worked much like the one in Figure 422, page 431, was in use as early as 1862. It is interesting to note that all the modern ways of lighting our buildings and streets have been invented and perfected during the last one hundred and twenty-five years.

Keystone View Co.

Fig. 406. An Early Lamp

At the right of the bowl you can see the crude wick which dipped into the fat or oil.

The sun furnishes us with light during the day. At night

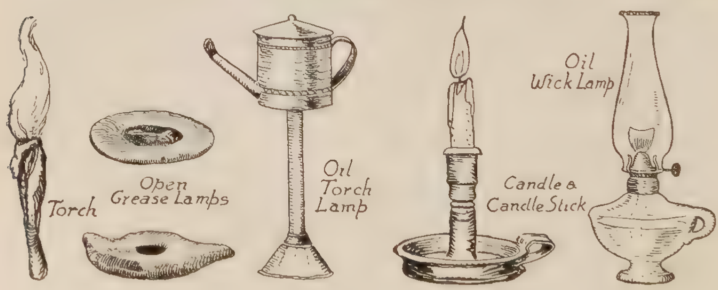
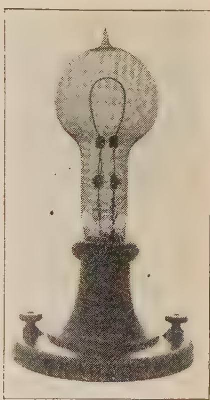


Fig. 407. From Torch to Kerosene Lamp

It required many many years for man to improve his methods of lighting by inventing these different devices.

various devices *illuminate* our buildings and streets with artificial light. In every case these devices involve the use of some

hot body which gives us light. It may be the glowing carbon particles in the flame of a candle, of a kerosene lamp, or of a burning gas jet, the hot glowing mantle of a gas light, or the hot filament of an electric-light bulb.



Edison Lamp Works

Fig. 408. Edison's First Electric Light

The filament was very large. The lamp looks much like our lamps of today.

Wherever and whenever material is extremely hot, it sends out light in all directions. You see an object, not because light goes from your eyes to the object, but because light comes from the object to your eyes. Light is a form of energy and may be produced in different ways. Meteors give off light as "shooting stars" when the friction of the air heats them; a piece of metal held in a fire gives light when it is heated by the chemical action in the fire; a filament or wire glows when the electricity which passes through it heats it; burning gas heats the gas mantle, and light results. It is evident that light is a form of energy which may be produced by transforming some other kind of energy. (See page 340.)

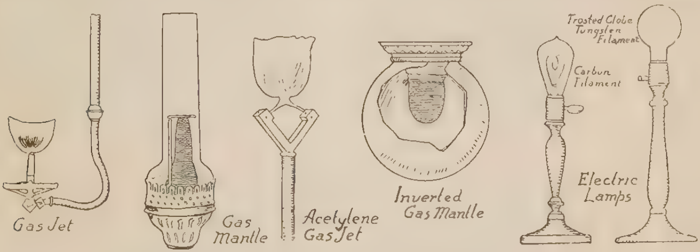


Fig. 409. Modern Lighting Devices

Devices like these are used today. The most modern source of light is the electric bulb with a tungsten filament.

You already know some of the characteristics of light energy. Among the properties of light are the following: light travels in

straight lines (Figure 410); light moves out from the source in all directions until it strikes something through which it cannot pass; the nearer you are to the source of light, the brighter the light shines; light readily passes through *transparent* materials like glass or air (see page 41); some materials, like tissue paper, oiled paper, and frosted glass, called *translucent* materials, allow some light to come through them but not enough to enable you to see through them; light cannot pass through *opaque* materials, like wood, metals, or rocks.

Fig. 410. Light Travels in Straight Lines

Unless the holes in the cardboards are on a straight line, the eye cannot see the light. Try it.

Through a study of these properties man has been able to improve his methods of lighting. He has learned that one source of light may be better than another, and he can select the proper source for a given purpose. Frosted windows or shades can be used to give a "soft" even light instead of a "hard" direct light. Light-colored walls may be used to brighten a room which receives but little light. The intensity or brightness of light can be measured, and lamps of the proper power can be selected. The most economical sources of light may be used. These are but a few of the great number of facts which most of us know. Why these are facts and how scientists have proved them, will furnish you with many interesting problems about light energy and the use you make of it every day of your life.

PROBLEM 1: HOW IS LIGHT FROM THE SUN USED FOR ILLUMINATION?

The sun is our best source of light. This form of energy comes from the sun to the earth, across the 93,000,000 miles of space at the rate of 186,000 miles per second, requiring only about eight minutes for the entire journey. So great is the amount of light sent out by the sun that even at this great distance the direct rays are so bright that they injure our eyes.

If this light came directly into our rooms through windows in the ceiling or in the roof, it would be not only unpleasant but injurious to the eye. To avoid the direct light and to make it possible to see out of our buildings, windows are placed in the sides of buildings. Thus most of the light which enters comes from the sky, but not directly from the sun.

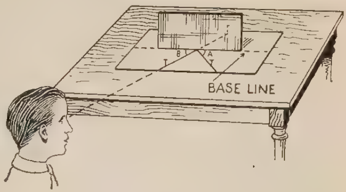


Fig. 411. How Light Is Reflected

Sunlight is reflected by the atmosphere. As the sun's rays come into the atmosphere, they strike innumerable small particles of air, water vapor, and dust.

Experiment 93: What happens when sunlight strikes dust particles?

Allow a beam of sunlight to enter a darkened room through a hole in a curtain or through a small opening between the curtain and the window frame. Fill the space through which the beam passes with chalk dust by clapping together two blackboard erasers. Is the beam of light visible now? Why?

The experiment helps you to understand how the sun's rays light the sky. The rays are reflected from the air, dust, and water-vapor particles and then come to the earth.

Let us see by an experiment how light is reflected.

Experiment 94: How is light reflected?

(*a*) Draw a line across the middle of a piece of paper and stand a mirror on this line, called the base line. Stick a pin in the paper a few inches in front of and to the right of the middle of the mirror. Close one eye and move the head until the open eye is level with the table and in front of the left edge of the mirror. Look at the image of the pin in the mirror. Place a mark on the base line at the point where you see the image in the mirror. Stick a pin a few inches in front of the mirror on the line along which you are sighting, as in Figure 411. Remove the mirror and draw a line from each pin to

the point which you made on the base line. These lines form two angles (A and B) with the base line. How do these angles compare in size? (If you know how to use a protractor, measure the number of degrees in the angles and compare them.)

(*b*) Repeat the experiment, changing the position of the first pin.

The light from the first pin goes to the mirror and is reflected to the eye. The angle between the ray of light which strikes the mirror and the mirror itself is called the *angle of incidence* (angle A, Figure 411). The angle between the reflected ray and the mirror is called the *angle of reflection* (angle B). From the experiment, how does the angle of incidence compare in size with the angle of reflection?

Not all surfaces reflect light as well as a mirror does. The kind of surface which the light strikes determines the amount of light which is reflected.

Experiment 95: How does the surface of a material affect the reflected light?

Hold a piece of heavy plate glass or a shiny metal surface in such position that the direct rays of sunlight strike it and then come to your eye. The reflected light is so bright that you should look at it for only an instant. Now use a piece of frosted glass or a piece of white rough paper instead of the smooth glass, and repeat the experiment. In which case is the reflected light more "blinding"? In which case does it seem to be more evenly distributed?

Diffused light is soft light. You are now ready to understand why the light from the sky is less bright and glaring than the direct sunlight. The rays from the sun come to the atmosphere along parallel lines. Some come directly through the air to the earth. Others strike the small particles of air, dust, and water vapor and are reflected. But the surfaces of the particles are so irregular and turned in so many different directions that the rays strike them at different angles. Since the angle of incidence equals the angle of reflection for every surface, the reflected rays come from the particles in many directions and mix together, or *diffuse* (Figure 412). This *diffused* light is

"soft," because the rays are mixed up, while the parallel rays from the sun are "hard" and blinding.

It is largely the reflected light from the sky that we depend upon for the natural lighting of our buildings. Coming through the transparent or translucent window, it strikes various parts of the room and is again reflected and diffused, making it still softer and more pleasing to the eye. If it were not for the dust particles, the sky would be dark except in the direction of the sun, and we should find it necessary to have our windows in the ceiling, so that the sunlight could come into our rooms and then be reflected from the floors and walls. In such case our rooms would be unbearably warm in the summer, because the radiant energy from the sun would come directly into them and there be changed to heat instead of being partly changed to heat when it strikes the dust particles in the air.

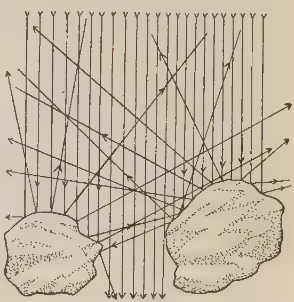


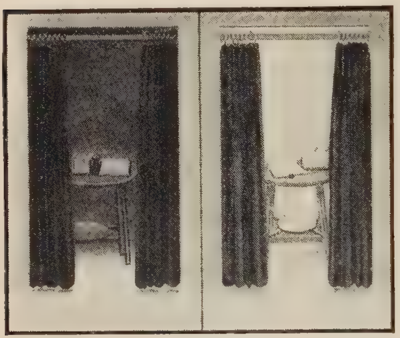
Fig. 412.
Diffusion of Light Rays

If a few particles cause the rays to be reflected and diffused in this way, you can imagine how thoroughly millions of particles would diffuse the light.

Several factors determine proper lighting. The amount of light which enters our rooms depends largely upon the window space and the kind of glass used in the windows. In order to provide the proper amount of light, it is generally agreed that the window space should be at least from one-sixth to one-fourth of the floor space. If it is one-fourth or more, a room may receive enough light even on a cloudy day.

The amount of light which enters a room is not the only factor to bear in mind in correct lighting. The color of the ceiling, the walls, the woodwork, and the furnishings has much to do with proper lighting. Dark-colored materials, as you already know, absorb much light, while light-colored materials reflect light. The window space and the kind of glass in the window may be

correctly planned for a room, and yet the interior may be so dark-colored that much light is absorbed. Figure 413 shows two rooms with the same window space but with walls and furnishings of different colors. If the ceiling and walls are light-colored, there is great reflection, which produces an even, soft, agreeable light in the room. On the other hand, a dark-colored interior receiving the same light may absorb so much that the room is very poorly illuminated.



Courtesy Illuminating Engineering Society

Fig. 413. Two Rooms Receiving the Same Amount of Light

Light-colored walls should be used in a room which has little window space. Why?

The position of the windows is another factor to be considered. Whenever possible they should reach to the ceiling. The higher the windows are the greater is the amount of light which is reflected from the ceiling. If the ceiling is light-colored, much light can be reflected from it, and the light then comes from above, properly diffused. Diffused light from above is the most desirable kind; it is nature's method of lighting, and our eyes are best adapted to it, for nearly all outside light comes from above.

Since the window space, the kind of glass, the color of the interior, and the position of the windows in a building are usually such that a room receives proper lighting on cloudy days, awnings, curtains, and shades are commonly used to regulate the light on bright days, as well as to keep out the direct rays of the sun. Usually the curtains and shades are made of translucent materials. Since these materials diffuse the light, they prevent the unpleasant and harmful reflections from direct sunlight. However, it should always be borne in mind that curtains and shades if not properly arranged may interfere with proper ventilation.

The direction from which the light comes is still another important thing to consider. As you have learned, light from above is most desirable, but usually we must get much light from the side. In general, for writing light from the left is best because the shadow of the hand is thus avoided. It should come from as high above our work as possible, however, to eliminate reflections. It should not come from the source in such a way that it is reflected from the page directly to our eyes (Figure 414). In factories, shops, laboratories, and stores where it is impossible to arrange materials so that they may be well lighted from one side, the sky-light method is always best. Saw-toothed roofs with windows facing north give the most satisfactory illumination, because the light from the north sky is thoroughly diffused and therefore "even" and "soft."

Fig. 414. Good and Bad Positions for Study

Which of the students has taken the best study position? Why?

Exercise 1. Examine your living-room at home and write a report on "The Lighting of Our Living-Room," including such points as the following:

1. Relation of window space to floor space.
2. Position of windows and direction of light.
3. Color of ceiling, walls, and furnishings.
4. Regulation of light.
5. Suggestions for improvement.

Exercise 2. Is your schoolroom properly lighted? Explain your answer.

Exercise 3. Which of the three persons in Figure 414 is using the light correctly? How could the position of the lamp or of the students be so changed that each student would receive the proper lighting on his work?

PROBLEM 2: HOW DO GAS LIGHTS FURNISH ARTIFICIAL LIGHT?

Before he discovered how to use electricity, man obtained his light from fire. Various kinds of candles, lamps, and gas burners were employed. All of these gave light when certain materials in the flame were heated until they glowed, or became incandescent. Since every flame contains burning gas, you may think of gas light as including candles, kerosene lamps, gasoline lamps, acetylene lamps, natural-gas burners, and artificial-gas burners. All gas light is produced in a similar way. There is always some solid material in the flame which is heated to incandescence. (See Experiment 56, page 239.) Our problem here, then, will be to understand how kerosene, gasoline, natural and artificial gas, and acetylene, the most common fuels for lighting purposes, produce flame and light in the simple devices of everyday use.

Kerosene is used for lighting. Those of you who have lived or visited in the country have often seen the common *kerosene lamp* shown at the right in Figure 407. The wick extends into the bowl. The kerosene, or coal oil as it is often called, rises to the top of the wick by *capillarity;* that is, by being attracted upward through the fine, thread-like openings between the fibers in the wick. When the lamp is lighted, the kerosene at the top of the wick changes to a gas, or vapor, and combines with the oxygen. Kerosene continues to rise in the wick so long as the lamp burns. As the wick slowly burns away, it is turned up by means of the screw at the right of the burner.

Kerosene is a *hydrocarbon* compound; that is, it is composed of hydrogen and carbon. Since the flame does not receive enough oxygen and also since the temperature is not hot enough to burn all of the carbon of the compound, some carbon escapes burning and rises through the flame, where it is heated to incandescence. The hydrogen burns, forming water. If the wick is properly trimmed, if it is not turned too high, and if the air holes at the bottom of the burner part are kept open by proper cleaning, most of the carbon is burned before it escapes

from the top of the flame. In such case there is little smoke. The products of burning are, then, water and carbon dioxide.

The more modern form of kerosene lamp is shown in Figure 415. This is often called the circular-wick kerosene lamp, because the wick is circular and extends all the way around the burner. Sometimes this lamp is called the center-draft kerosene lamp.

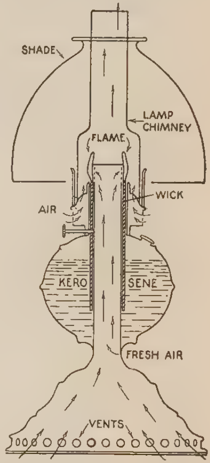


Fig. 415. A Center-Draft Kerosene Lamp

By the use of a shade of frosted glass this lamp gives a soft white light.

Exercise 4. If the kerosene lamp in Figure 415 smokes, what may be done to stop the smoking?

Exercise 5. Examine Figure 415 and explain: (*a*) how the wick is adjusted; (*b*) how the flame gets air; (*c*) how the flame gets kerosene vapor; (*d*) why the chimney is used over the flame; (*e*) why this lamp gives more light than the kerosene lamp in Figure 407.

Gas is used in many regions. Two kinds of gas are used for lighting in various parts of our country. In certain regions natural gas is obtained from wells similar to the petroleum wells described on page 248. Where natural gas is not available, artificial gas is manufactured from soft coal. (See page 246.) These two kinds of gas are commonly used where electricity cannot be produced or obtained at low cost.

Two kinds of burners, the open flame and the burner fitted with a mantle, are the means employed for producing gas light. The open flame is often nothing more than a flame at the end of the pipe. A valve is turned to allow the gas to escape, and the gas is lighted. The gas is composed largely of compounds of two elements, hydrogen and carbon. The hydrogen burns with a colorless flame, but some of the carbon particles become heated and glow, causing a luminous flame. Sometimes a fish-tail flame-spreader, or "lava-tip" is placed in the end of the

gas pipe, as shown in Figure 416. The fish-tail burner spreads the flame so that it gives more light, and a frosted-glass shade may be placed over the flame to diffuse the light and make it more pleasing. The open flames give unsatisfactory illumination, and are also objectionable because they smoke the walls and ceilings of houses.

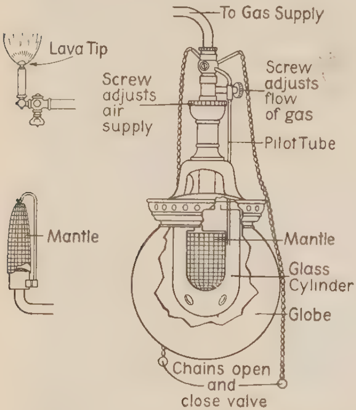


Fig. 416. Types of Gas Lamps

A great improvement on the open flame is the burner fitted with a mantle. The burner is much like the Bunsen burner which you know from Unit VIII, page 215. It is attached to the end of the gas pipe. The amount of air entering at the base can be regulated so that all of the carbon is burned, and thus a very hot blue flame may be produced. Over this blue flame is the cup- or thimble-shaped *mantle* (Figure 416) composed of a meshwork of the white oxides of two rare metals, cerium and thorium. When the mantle is heated, it becomes incandescent and gives off a very bright white light.

Gasoline lamps are of two kinds. A portable gasoline lamp in quite common use is shown in Figure 417. The gasoline is contained in the tank at the top. When the lamp is to be lighted, the flame of a small alcohol lamp or the flame of a small ball of asbestos wool soaked in alcohol is brought under the *gas vaporizer*, heating it until it is quite hot. (This is sometimes done by opening the valve and

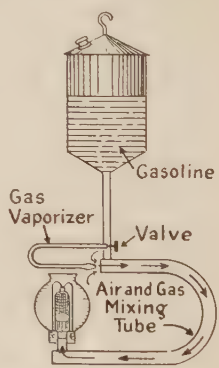


Fig. 417. A Portable Gasoline Lamp

Often one sees lamps of this type fitted with fish-tail burners.

allowing a little gasoline to flow out of the tube into a small boat-shaped metal vessel directly under the vaporizing tube, then closing the valve and lighting the gasoline.) When the vaporizing tube is hot and the gasoline in it has been changed to a gas, the valve is opened slightly. This allows a fresh supply of gasoline gas to enter the large *mixing tube*, carrying air with it (Figure 417), and the mixture passes to the burner, where it is lighted. The mixture of gas and air passes through a wire screen or gauze over the top of the burner and burns with a hot bluish flame. The hot gases of the flame passing upward keep the vaporizing tube at the proper temperature to vaporize the gasoline as it is needed. The flame gives but little light because there are in it few solid particles of carbon, the gas being almost completely burned by the large amount of air admitted. A mantle makes the flame light-giving, or luminous.

Fig. 418. A Pressure Gasoline Lamp

See Figure 419 for the construction of this lamp.

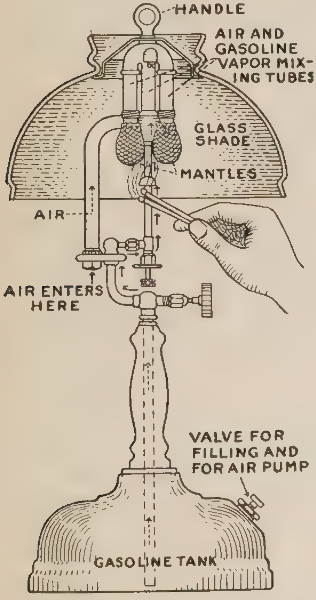


Fig. 419. Construction of the Pressure Lamp

What step in the operation of the lamp is being taken in this figure?

A second form of gasoline lamp (Figures 418 and 419) has the gasoline tank at the bottom. To operate this lamp, air is first pumped into the space above the gasoline, through a valve at the top of the reservoir (Figure 419),

by means of an ordinary bicycle pump. The vaporizing tube is then heated as in the case of the previously described lamp, the thumb-screw is turned, opening the valve, and the gas is lighted at the mantle, which in this form of portable lamp usually hangs downward. The only essential difference between this lamp and the former one is the method of supplying gasoline to the vaporizing tube. Here compressed air is used to force the fuel to the vaporizing tube, while in the former, where the reservoir was above the flame, gravity does the work.

Fig. 420. A Bicycle Acetylene Lamp

See Figure 421 for the construction of the lamp.

For lighting entire buildings where many lamps are required, a gasoline-gas machine is used. This is much like the portable lamp last discussed. It consists of a reservoir, tubes leading to different rooms or different parts of the same room, and a number of lamps quite similar to the one last described. To avoid danger of fire and explosion the reservoir is often placed in a small building some distance from the building to be lighted. For very large lighting plants a blower is used to force air into the reservoir. The gasoline is forced out through a pipe and is vaporized and mixed with air before it reaches the lamp.

Exercise 6. Recalling your study of the Bunsen burner (page 215), explain why the air must be carefully regulated in a gasoline-gas lamp to obtain the best light from the mantle.

Acetylene gas does not require a mantle. Acetylene gas furnishes a very bright white light, more nearly like sunlight than that of any other gas. It is made by the action of water on calcium carbide. One of the simplest devices which uses acetylene is the bicycle lamp (Figures 420 and 421). Water is allowed to drop from the reservoir upon the calcium carbide in

the generator. The wick prevents the water from flowing too rapidly. The acetylene produced by the chemical action of the water and the calcium carbide escapes through the burner at the top, mixes with air, and burns with an intense white flame. The pressure of the gas in the reservoir forces the gas out of the tube at a considerable speed. The amount of water necessary can be regulated by a valve.

A knowledge of the operation of the bicycle lamp makes it easy to understand how acetylene can be used for lighting buildings. The gas may be supplied to the burners from large tanks containing compressed acetylene, or by devices similar to the generator of the bicycle lamp.

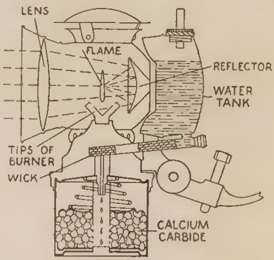


Fig. 421. Construction of a Bicycle Acetylene Lamp

The rays of light from the flame strike the reflector and then pass through the lens to the road ahead.

Exercise 7. What is the purpose of the tube leading from the water reservoir to the generator (Figure 421)?

Exercise 8. When a bicycle is ridden over a rough road, the flame of the bicycle lamp often increases in size until it comes out of the top of the lamp. Explain.

PROBLEM 3: HOW DOES ELECTRICITY GIVE LIGHT?

Electric light has become the modern source of illumination where a sufficient current of electricity is available. Windmills, water wheels or tubines, steam engines, and gas engines run dynamos for furnishing electric current to light our buildings and streets directly, or to charge storage batteries from which the electric current may be obtained when needed.

Electricity produces heat and light. Since the electricity obtained from dynamos is the same as that generated by cells, you can use the electric current from cells to find out how electricity causes heat and light. You know that certain materials, called conductors, carry the electric current, and that some of these conductors, like the wires in an electric bulb, become very hot when the current passes through them.

Experiment 96: Are all conductors heated equally by an electric current?

(*a*) Attach an insulated copper wire one foot long (No. 22 to No. 16) to the electrodes of a dry cell. Feel the wire. Does it change its temperature? (If a storage battery is available, repeat the experiment, using the battery instead of the dry cell.)

(*b*) Repeat the experiment, using the dry cell and a piece of No. 30 insulated copper wire one foot long. Is the wire heated by the current?

(*c*) If different sizes of iron wire are available, repeat the experiment, using iron wire of the same sizes as the copper wires. Note that the iron wires are heated much more than the copper wires.

If you try many different conductors in this way, you find that some materials are heated much more than others and that a wire of smaller diameter always becomes hotter than a large wire of the same material. Also, if you use the storage battery or several cells to produce a strong current, you find that the temperature of a conductor depends upon the amount of current which flows through the wire.

No material is a perfect conductor of electricity; all offer some resistance to the current. This electrical resistance, much like friction, transforms some of the electric energy into heat. When the resistance is great, a considerable part of the electric energy is changed to heat, and the conductor becomes hot. Table XIV shows how some common materials vary in their resistance to the electric current. In this table it is understood that the materials are of the same diameter and length and that the same voltage is used to send the current through them.

TABLE XIV: RESISTANCE OF COMMON MATERIALS COMPARED TO SILVER

Silver	1.00	German Silver*	14.20
Copper	1.11	Mercury	63.00
Aluminum	1.94	Tungsten	2.35
Iron (soft)	6.00	Manganin†	1.91
Platinum	7.20	Constantin†	2.30

*Resistance depends upon composition of the alloy.
†Alloys used in making wires for electric heaters.

Exercise 9. From Table XIV list the materials in the order of their ability to conduct an electric current, starting with silver.

When wires or other conductors become hot enough, they send out light. If the conductor is heated to a very high temperature, the light produced is nearly white. At such high temperatures most materials burn; so it is necessary to place the conductor in a bulb which contains no oxygen.

Edison made the first electric-light bulb. Thomas Edison about fifty years ago became interested in this problem of electric lighting, and after many years of careful study invented the electric, or incandescent, bulb. His scientific genius led him to see that the problem could be solved by the use of a *filament*, or thread, made of a material which would not easily melt or vaporize when heated by an electric current. He also found it necessary to keep air away from the filament so that it would not burn. With this idea in mind he sought to make a very small thread of carbon and to place it in a container from which the air could be exhausted. By making carbon filaments from various materials like cotton and bamboo, placing them inside bulbs and removing the air, and connecting the filaments with a source of electricity, he succeeded in perfecting an electric-light bulb which gave satisfactory illumination (Figure 409). It was in 1880 that this wonderful invention was made.

Tungsten filaments are now used. Many improvements on this crude light have been made by Edison and other scientists. Today the much more efficient *tungsten-filament lights* are rapidly displacing those with carbon filaments.

Experiment 97: How is the electric bulb constructed?

(*a*) Examine an electric-light bulb and the socket to see how the electricity enters and passes through the bulb.

(*b*) Observe how the filament is attached to the wires which lead through the glass to the outside connections. How is the filament suspended to make it spread over considerable space? Why is this done?

(*c*) Compare the construction of a carbon-filament light and a tungsten light.

(*d*) Take a "burned out" carbon-filament bulb, place it under water, and break off the tip of the bulb with a pair of pliers. Why does the water enter the bulb? Does it completely fill with water? If not, can you guess why it does not?

(*e*) If a "burned out" nitrogen-filled tungsten-filament bulb is available, repeat (*d*), using it instead of a carbon-filament bulb. Result? Can you explain the result?

The tungsten bulb is superior to the carbon bulb in both the amount of light produced and in the color of the light. For these reasons the tungsten-filament lamp has largely displaced the carbon lamp. It requires only about one-fourth as much electricity to produce the same amount of light, gives a whiter light, and does not "burn out" so quickly, although it is more easily broken. Such lights were made possible when scientists learned how to draw the metal tungsten into very fine wires.

In recent years the tungsten bulbs have been filled with gases like nitrogen and argon which will not combine with the filament. The air is first removed from the bulb as completely as possible, and the nitrogen or argon is then introduced and the bulb is sealed. The presence of these gases allows the filaments tc be heated to a higher temperature than is possible in vacuum bulbs without vaporizing the metal. This increases the light-giving qualities of the filament. While the vacuum tungsten bulb gives about four times as much light as the carbon bulb for the same cost of electricity, the gas-filled tungsten bulb gives about eight times as much.

The arc lamp is very efficient. Another form of electric light, formerly much used for street lighting and now often seen in stereopticons and motion-picture machines, is the electric *arc lamp*. This lamp consists of a mechanism for holding two carbon rods, or electrodes, connected with the ordinary lighting current (Figure 422). If the rods are brought into contact, end to end, the ends become very hot. If they are separated by from one-fourth to one-half inch, the current continues to flow across the gap between the rods, conducted by a stream of carbon vapor. This incandescent vapor is

called the *electric arc*. The position of the rods can be adjusted by hand or controlled automatically. Sometimes the carbon rods have cores made of different light-giving materials, which vaporize and produce what is known as the *flaming arc*. The ordinary carbon-rod arc gives about as much light for the same current of electricity as the vacuum tungsten lamp. The flaming arc lamp is much more efficient, often giving nearly twice as much light for the same electrical energy as the gas-filled tungsten lamp.

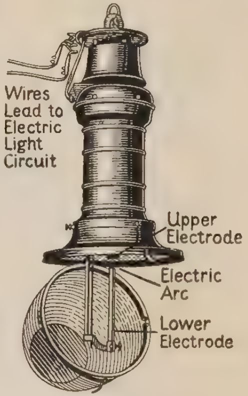


Fig. 422. A Modern Electric Arc Lamp

The arc forms between the upper and lower electrodes. When the globe is closed, the reflector at the bottom reflects the light upward through the frosted globe.

Exercise 10. Explain why some electric bulbs cause a loud report like an explosion when they break.

Exercise 11. Why do electric toasters and electric irons give heat but little light? How are they constructed? What would happen if a very strong current of electricity were sent through the toaster?

Exercise 12. Enumerate the advantages of electric light over other forms of artificial light.

PROBLEM 4: HOW ARE BUILDINGS WIRED FOR ELECTRIC LIGHTING?

Since the electric current for practical lighting comes from powerful dynamos or large storage batteries, we must exercise care in protecting ourselves from the danger of severe shocks, and our buildings from the danger of fire. On page 253 you found a list of the various ways by which electricity may cause destructive fires. You now want to know, also, how the lead-in wires, the fuse box, and the electric lamps are connected to avoid danger of fire and shock, and to make it possible to have light from any bulb in the building by merely turning a switch or pressing a button.

Buildings must be scientifically wired. Figure 423 shows how electricity is brought from the power plant to a house. The

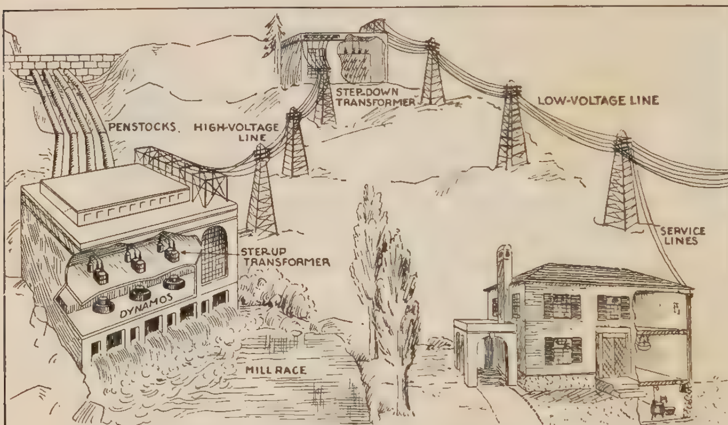


Fig. 423. An Electric Power Plant

Water passes from the dam through the penstocks to the turbines in the basement of the power house. The turbines turn the dynamos in the dynamo room above. The dynamos send the current to the step-up *transformers*, which increase the voltage of the current. This high voltage is carried by transmission lines for many miles to local power stations, where the voltage is reduced before the current goes to the residences.

voltage of the current from the generator which supplies the electrical energy must be changed to the proper voltage for the electric lights in the house. The E. M. F. of the current which enters the building is usually 110 volts. Two heavy insulated wires lead to the house, one carrying the current into the building and the other carrying it back to the transformer. If the generator gives a current with a voltage of 110 volts, no step-down transformer is necessary, and the wires leading to the building come directly from the generator. Inside the wall where the wires enter the house (Figure 425) is a large switch with two *fuses*, as shown in Figure 424, which are encased in an asbestos-lined box. From this switch the wires lead through the meter

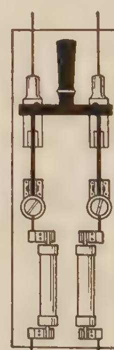


Fig. 424. A Switch and Fuse

and then to a second fuse box and switch. If the building is large enough, several wires lead from each pole of the second switch, and different pairs of these wires, one wire from each pole of the switch, go to the branch fuse boxes located in different parts of the building. From each of these fuse boxes two

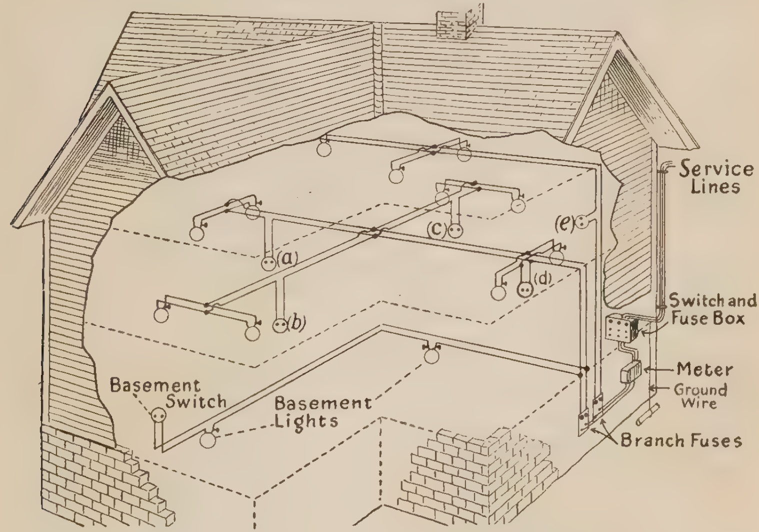


Fig. 425. Electric Wiring of a Small House

The lights in the basement are connected in series with the basement switch. The lights on the first floor and in the attic are connected in parallel. The letters in parentheses indicate wall switches. See Figure 423 for connections of service lines.

wires lead to the different rooms where the lights and small wall switches are connected to make the circuit complete.

All wires inside the building are usually placed inside iron pipes, or *conduits*, to prevent short-circuits. With such conduits for the wires, the proper construction of fuse boxes, and the use of proper fuses there is little danger of fire. If a short-circuit is made in any way on any part of the line, the fuse wires, being made of a metal which melts at a low temperature, immediately melt and break the part of the circuit which they control. The fuses in the first box are large, that is, can carry

a heavy current, while those in the branch fuse boxes are small. A short-circuit in any part of the building will, therefore, "burn out" the fuse in the branch box. The lights in other parts of the building are then not affected.

Electric lights are usually connected in parallel. In the wiring of the house (Figure 425), you observe that all but the basement lights are connected across two *lead wires*, as illustrated in Figure 426. This method of connecting lamps is called connecting in parallel. You see that any lamps can be turned off without breaking the circuit in other lamps.

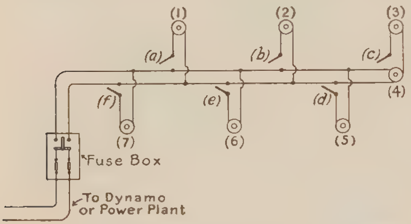


Fig. 426. Parallel Connection of Lamps

The electric light bulbs are shown by the circles numbered (1), (2), (3), (4), (5), (6), and (7). The main wires lead down the hall of a building, while the branches go to the lamps in the rooms. The wall switches are shown at (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*). Any lamp can be turned on without disturbing the others.

But there is one fact about connecting lamps in parallel which you should remember; namely, that when two or more lamps are connected in parallel across the lead wires, they allow more current to flow through the line than a single lamp does. It works just like putting two or three pipes instead of a single pipe between two tanks of water. Therefore, too many lamps should not be connected across the lead wires from a branch fuse box, because the current strength would then be greater than the wire could carry with safety. Fuses are inserted in the circuit to eliminate this danger. Usually the fuses in the branch boxes will carry 5 or 10 amperes. Since ordinary electric bulbs will carry about one-half ampere on a 110 volt circuit, you see that 12 such lamps in parallel allow about 6 amperes to flow. This is more current than a five-ampere fuse can carry, and it is therefore necessary to have fewer lamps on the branch circuit or to use a fuse with greater capacity. The former plan is the better, because the smaller fuse offers more protection against a short-circuit in the line. If a heavier fuse is used, so many

electrical devices may be put in the circuit that the current may heat the wire enough to burn off the insulation and start a fire.

The construction of the fuses varies for different uses. In the branch fuse boxes screw-plug fuses (Figure 427) are commonly used. If an old fuse is available, break it with a hammer and find the small wire inside. Hold this in a flame and note how easily it melts. For the first and second fuse boxes, cartridge fuses are more common. In these a heavy wire of low-melting alloy is surrounded by finely powdered marble, clay, or other non-combustible material. The powdered material serves as protection against the hot metal when the fuse "burns out," just as the porcelain and isinglass serve in the screw-plug fuse.

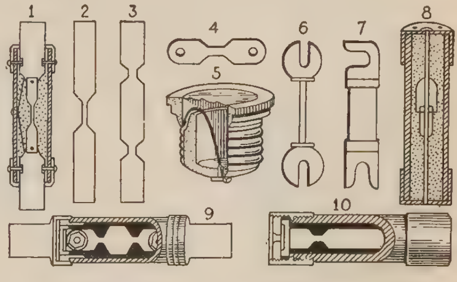


Fig. 427. Types of Fuses in Common Use

Numbers 2, 3, 4, 6, and 7 are commonly called link fuses. They are bare metal bars or wires. Numbers 1, 8, 9, and 10 are cartridge fuses. Number 5 is the common screw-plug fuse.

Exercise 13. Explain all that happens in the line and in the lamps when you turn on the switch of an electric light.

Exercise 14. Why are fuses in the first fuse box of a large building made to carry a current of from 30 to 150 or more amperes, while those in the branch fuse boxes have a capacity of only 5 or 10 amperes?

Exercise 15. Why are electric lamps in buildings not connected in series? (See page 399.)

PROBLEM 5: HOW ARE THE POWER AND COST OF ARTIFICIAL LIGHT MEASURED?

Light is measured in candle-power. The amount of light which is given off by any source can be measured. Scientists have given us a unit for measuring the *intensity of light*. This unit is called the *candle-power*. It formerly signified the brightness of the flame of a sperm (whale-oil) candle, seven-eighths

of an inch in diameter, burning at the rate of 120 grains, or 7.77 grams, of sperm an hour. Because it is impossible to make candles which give exactly the same amount of light, scientists now use electric-light bulbs to measure candle-power.

By the use of the unit candle-power, it is possible to measure the light from the different devices in our homes. A kerosene lamp gives from 10 to 15 candle-power, depending upon the size and height of the wick; an ordinary flat gas flame gives from 15 to 25 candle-power; a gas mantle for ordinary gas lighting has a candle-power of from 50 to 100; mantles on gasoline gas burners usually give from 100 to 150 candle-power; incandescent electric bulbs vary according to the size of the bulb, being commonly made in such sizes as 4, 8, 16, 32, 60, 100, and as high as 1000 candle-power; an electric arc may give as many as 1000 to 2000 candle-power. The amount of light from any of the gas lighting appliances depends upon the rate at which the fuel burns. It is, therefore, not possible to state more exactly the candle-power of these sources.

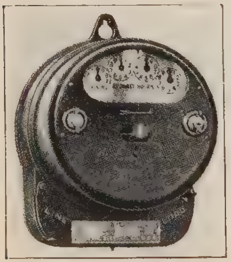


Fig. 428. An Electric Meter

No electricity has passed through this meter. All hands point to the zero marks.

The power of electric light is measured in watts. In electric lights it is more common to state the power of the lamp in *watts*. The watt is the unit for measuring the power of the electricity used. One watt of power is produced when a force of one volt sends one ampere of current through a wire (volts times amperes equals watts). The kind of filament in a bulb determines how much light will be given when a certain electrical power is used. This means that the relation between watts and candle-power depends upon the kind of filament.

The ordinary carbon-filament lamp requires about 3.1 watts per candle-power; the tungsten lamp requires about 1.25 watts per candle-power; and the gas-filled tungsten requires only about .5 watt per candle-power. These figures are for the

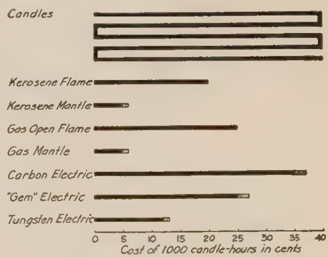
ordinary 110-volt lighting circuit. If you examine an electric bulb and find it marked 25 watts (25W) or 50 watts (50W), you can know how many candle-power it gives. If it is a 50-watt Mazda (gas-filled tungsten) it gives, on a 110-volt circuit, 50 divided by about .5, or approximately 100 candle-power.

Exercise 16. What is the candle-power of light given by a 100-watt carbon lamp on a 110-volt circuit?

Exercise 17. An electric bulb (tungsten vacuum bulb) gives a candle-power of 80. How many units of electric power does it use?

Exercise 18. How much current flows through a 60-watt lamp connected in a 110-volt circuit?

Cost of artificial light is easily determined. For illuminating gas, the *meter* measures the volume used, and the cost can be determined. (See page 248.) In electric lighting the cost depends upon the amount of electric power used, which is measured by an electric meter (Figure 428). As the current is used, the hands on the dial are turned by small gear wheels inside the meter. The electric-meter dials (Figures 430 and 431) show the number of *kilowatt-hours* used between the time of two different readings. (A kilowatt-hour means that 1000 watts of electrical power have been used for one hour.) Since electrical power is sold by the kilowatt-hour, the cost of lighting a building for a certain period is determined by reading the meter at the beginning and end of that period and multiplying the difference by the cost per kilowatt-hour. Figure 429 gives you some idea of the relative cost of candle light as compared with other more modern sources of light.



Courtesy U. S. Bureau of Standards

Fig. 429. Relative Costs of Various Methods of Lighting

The lengths of the lines show the relative costs of the same amount of light from the different sources.

Exercise 19. From Figures 430 and 431 find how many kilowatt-hours were used during the interval between the two readings. Find the cost of electricity per kilowatt-hour in your community and determine what the bill for electricity would be.

PROBLEM 6: HOW IS ARTIFICIAL LIGHT REGULATED IN OUR BUILDINGS?

Your eyes are delicate mechanisms and need to be considered in lighting. (See page 166.) All lighting in buildings, whether natural or artificial, should be regulated to provide the least strain on the eyes and to allow you to see any object clearly. The amount of light, the color of the light, the direction from which the light comes to the eye, and the method of lighting are four very important things that must be considered in regulating light so that it will be most pleasing.

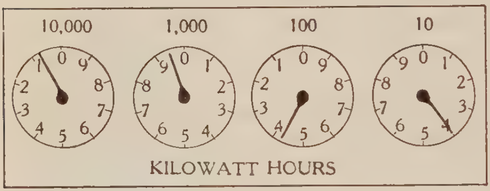


Fig. 430. One Reading of the Meter

The hands left to right turn in opposite directions. For one turn of the hand at the left, the one to its right makes 10 turns, the third hand makes 100 turns, and the fourth makes 1000 turns. The reading is 944 kilowatt-hours.

Intensity of light depends on distance from source. The amount of light received from any source depends, as you know, upon the brightness or intensity of the source and upon the distance from the source. Evidently, an ordinary electric lamp gives out much more light than a candle does because the source is brighter.

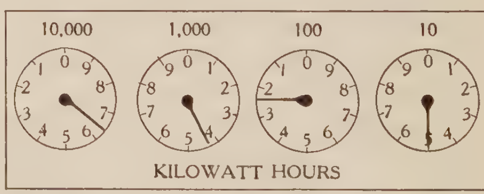


Fig. 431. A Later Reading of the Meter

Compare this with Figure 430. The hand at the left shows between six and seven thousand kilowatt-hours. What is the complete reading?

But if the lamp is far away and the candle is near, the candle may give more light or illumination on your table or desk.

Let us see how the distance from a source determines the amount of light which comes from that source.

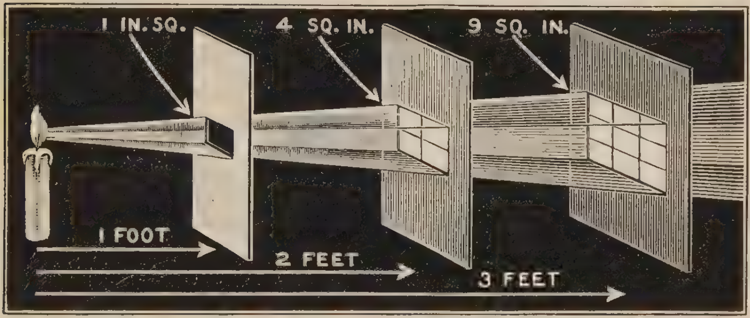


Fig. 432. Intensity of Light

The intensity of the light becomes less and less as the distance from the light increases.

Experiment 98: How does the distance from a source of light determine the illumination which the light gives?

In a dark room place a candle or electric flash-light one foot from a cardboard which has a hole one inch square at the center (Figure 432). Allow the light to pass through the hole in the first cardboard and strike a second cardboard, which is marked off in square inches and which is held two feet from the candle. How many square inches does the beam of light cover on the second cardboard? Move the second cardboard three feet from the candle. How many square inches of space are covered by the beam of light?

From the experiment you learn that a beam of light which is one square inch in cross-section at a distance of one foot from the source spreads until it covers four square inches at a distance of two feet, and nine square inches at a distance of three feet from the source. If the same light spreads over more space, the illumination must be less. At a distance of two feet the space covered by the beam is twice as long and twice as broad,

or four times as large as at a distance of one foot. Similarly, at a distance of three feet it is three times as long and three times as broad, or nine times as large. You see that a light gives only one-fourth as much illumination at a distance of two feet as it does at a distance of one foot. Similarly, at a distance of three feet it gives only one-ninth as much as it does at one foot from the source.

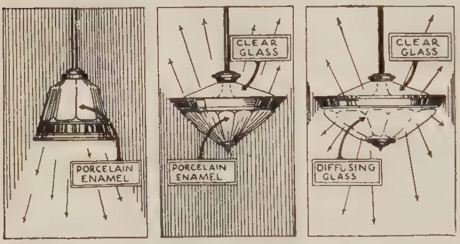


Fig. 433. Three Methods of Lighting

At the left is a direct-lighting fixture; the light is reflected downward. In the middle is an indirect lighting fixture; the light is reflected to the ceiling by the white inner surface of the opaque porcelain enamel. At the right is a semi-direct fixture; some of the light goes to the ceiling and some passes downward through the frosted glass bowl.

Exercise 20. How does the illumination at a distance of six feet from an electric lamp compare with the illumination at a distance of one foot? At a distance of two feet?

Exercise 21. State a general rule which gives the relation between the intensity of light and the distance from the source.

In artificial lighting, as in natural lighting, the amount of light in a room is of no greater importance than the softness of the light. The correct amount of diffused light is the best possible for the eye. It is this which you should always try to obtain, especially for reading. But remember that the direction from which the light comes is also important. (See page 421.)

Several methods of lighting are employed. Three common methods of lighting rooms with electric lights are the *direct* method, the *semi-direct*, and the *indirect* method (Figure 433). In the first method the light comes directly from the source to the table or place of work. The bulb may be made of frosted glass to diffuse the light, or it may be a plain glass bulb. In either case the light may be glaring and unpleasant or tiresome

to the eye. Little light is wasted in this way, however. Shades or reflectors may be used to make the light more intense.

In the semi-direct method a translucent frosted bowl is placed under the lamp. Some of the light passes through the bowl and is diffused; some is reflected by the bowl to the ceiling and then comes back to the room. This combination of diffused light and diffused reflected light is pleasing to the eye. It tires the eye far less than the light received by the direct method.

Courtesy Edison Lamp Works

Fig. 434. A Good Reading Position

This man is not subjecting his eyes to the strain of incorrect lighting. Why?

The system which is being used more and more in modern buildings is the indirect method. The bowl under the light is opaque, allowing no light to come directly to the lower part of the room. It is all reflected to the ceiling and then comes back into the room. The ceiling is of such material and color that the light is thoroughly diffused and quite white. It is the nearest approach to diffused sunlight and is, therefore, very soft and pleasing to the eye. The same effect is produced in many modern buildings by placing the lights in recesses around the top of the walls of the room. The light is then reflected from the ceiling, no light coming directly from the source to the eye or to the lower part of the room.

Exercise 22. Which of the three methods of lighting just described do you consider most economical from a financial standpoint? From a hygienic standpoint? Give your reasons.

Exercise 23. In writing at a table at night where would you place a portable reading lamp to get the most pleasing and least tiresome light? Make a rough drawing to illustrate your answer.

Exercise 24. Explain why the man in Figure 434 has taken a good position for reading.

Good illumination in a factory or workshop is quite as important as good illumination in the home or school. This is especially true in large factories where many men are employed.

Exercise 25. From your study of this unit state under each of the following effects of good lighting in a factory the reasons for these effects: (*a*) fewer accidents, (*b*) better quality of manufactured goods, (*c*) greater order and neatness, (*d*) lower cost of manufacture, (*e*) better health of the workmen.

Review Exercise on Unit XV. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit XV and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT XV

1. Name as many electrical devices as you can which make use of copper wire.

2. People sometimes place a penny or a copper wire back of a screw fuse-plug to complete the circuit when the fuse is burned out. Why is this a dangerous practice?

3. If an ammeter is available, connect it in line with three or four lamps connected in parallel. By screwing out one lamp at a time determine the current which flows through different numbers of lamps. If the voltage of the circuit is known, you can determine the resistance of the lamps.

4. Make a plan of an acetylene-gas lighting plant for a country home where electricity is not available.

5. Make a drawing to show why frosted bulbs give a softer light than bulbs made of plain glass. Explain your drawing.

6. Write to the manufacturer of a gasoline lamp or kerosene lamp, asking for drawings and descriptive material which explain the operation of the lamp. Outline your knowledge gained by examining the material you receive, and present it to the class.

7. Many one-story factories get their light from skylights which face the north. Explain the reasons for such construction.

8. Smoked glass is often used to observe the sun during an eclipse. How does such glass protect the eye?

9. School rooms are usually planned so that the light will enter from the left. Why?

10. In cities the walls of rooms are generally cleaned or refinished every year. Explain why this is necessary.

UNIT XVI

COMMUNICATING WITH OUR NEIGHBORS

Preliminary Exercises

1. How many different ways of sending messages do you know? List them.

2. In your list for Exercise 1 place a check opposite each way which depends upon the human voice.

3. Mention several ways in which each of the following means of communication is of use: your voice, signalling by light, newspapers and other printed materials, the doorbell, the buzzer, the telegraph, the telephone, the wireless telegraph, and the wireless telephone.

4. Which of the methods mentioned in Exercise 3 do you consider the most important to the world in general? Why?

5. Which of the ways mentioned in Exercise 3 is of the greatest value to you? Why?

6. What materials do you need to make an electric bell work?

7. What sources of electricity are used to operate devices for sending messages?

8. What is a "code" message?

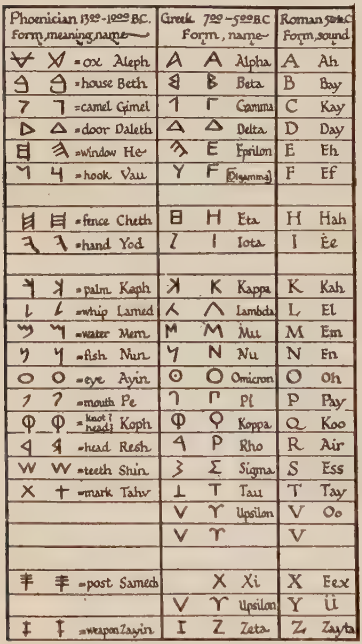
9. How does your weather report depend upon communication?

10. Of what importance is communication to civilization? To our national spirit? To business?

THE STORY OF UNIT XVI

Communication is the means by which man has learned to live with others. Without the ability to speak, write, and read little progress could be made. Man would find it necessary to live unto himself, for he could not learn from others nor could he give his ideas to others. Under such conditions he could not hope to understand nature's forces and materials; neither could he give to future generations the results of his thinking.

It must have been early in his family life that man sought some means of expression. Probably the first methods of intercourse with family and neighbors were expressions of the face or noises which showed fear, surprise, anger, or other emotions. Later he came to use his hands and head to make signs which carried meaning to his companions. Pointing or beckoning with the hand was, perhaps, one of the earliest ways of giving crude directions and of conveying thought to others.



From *The Story of the Alphabet.* © Norman T. A. Munder and Co. Used by permission.

Fig. 435. Early Forms of Writing

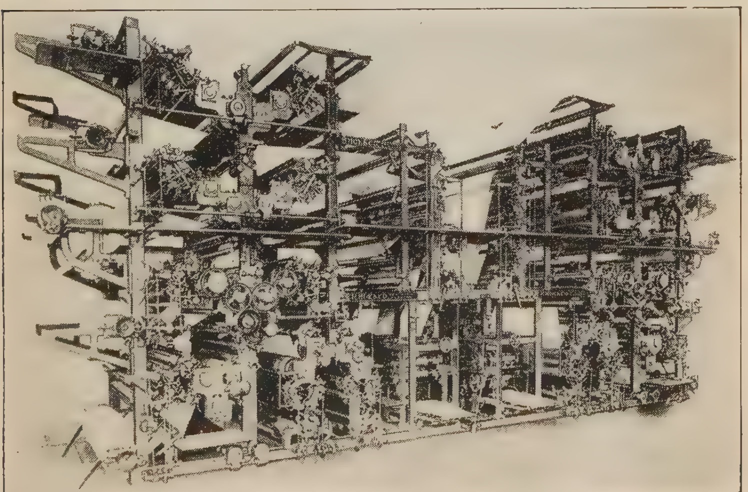
Compare letters or signs in the first two columns with the Roman letters which we use today. You will observe that some of our letters were not used by the Romans. Which ones are missing?

Through the many centuries there gradually developed various other methods of communication. Man learned to use his voice. This resulted in a spoken language, which was in its early stages undoubtedly little more than grunts. During the same time crude methods of picture-writing and of making symbols for ideas led to a written language (Figure 435). In time, speaking and writing, as we know them today, became man's means of intercourse. Thousands of years later printing was invented (Figure 436). After some centuries of improvement in printing, we have today complicated typesetting machines and great printing presses for preparing books, magazines, and newspapers in an efficient way (Figure 437). From the written and printed page man can profit by the recorded

knowledge of the past generations, as well as by the knowledge of what people of his own time all over the world are thinking and doing. Progress can be made to the extent that such intercourse is carried on.

Fig. 436. An Early Printing Press

Another equally difficult problem had to be solved by man. With the development of speaking, writing, and printing he had to find ways by which his spoken or written ideas could be carried quickly from one place to another, for, by this period in the development of communication, towns and villages had been established far and wide. The simple methods of using puffs of smoke,



Underwood and Underwood

Fig. 437. A Modern Printing Press

This machine prints and folds 300,000 eight-page newspapers an hour.

flashes of light, and other crude ways were no longer practical. Runners and riders could carry messages at considerable speed to other communities (Figure 438), but these ways were in time replaced by more modern methods. The growth of roads, railroads, and steamships helped to solve the problem by carrying the messages, or mail, great distances in a short time.

Courtesy First National Bank, St. Joseph, Mo.

Fig. 438. The Pony Express

The rider is off with the mail for villages or settlements across the plains.

Even with the development of methods of rapid transportation the world demanded still more speedy means of communication. Newspapers, letters, magazines, and books could be transported by road, rail, and water, but the more urgent messages of business and of world affairs, and the need for spreading news more rapidly required better methods of intercourse between communities. One force or energy which had not been used was electricity. Here was a possibility, and men began to seek for and to find ways to use it.

On May 24, 1844, and on June 7, 1875, two historic messages were sent by electricity. The first was the message by telegraph from Washington to Baltimore, "What hath God wrought?" Samuel F. B. Morse had proved to the public the success of

telegraphic communication over a distance of forty miles (Figure 439). The second was the telephonic message sent by

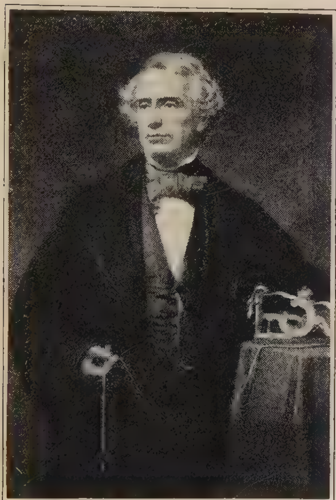


Fig. 439. Samuel F. B. Morse and His Telegraph

The small instrument operated by the electric current from the sending station made a record of the message on paper tape as it passed through the recorder.

Keystone View Co.

Fig. 440. Alexander Graham Bell

The picture shows Mr. Bell opening the first long-distance telephone line between New York and Chicago. This took place in October, 1892, seventeen years after he invented the telephone.

Alexander Graham Bell (Figure 440) to his assistant, Thomas Watson, "Mr. Watson, please come here; I want you." Morse and Bell had made use of the previous electric discoveries of many scientists, and had given us two of the greatest inventions of the nineteenth century.

When you include with these two inventions the electric buzzer, the electric bell, the ocean cables, and radio, you can understand how electric communication has completely changed man's way of living and carrying on his business. The earlier means of communication, such as messengers on foot or on

horseback, puffs of smoke from hill tops, and even mail for important messages, have given way to the current of electricity through wires and the waves of wireless. News, warnings of forest fires, floods, and frosts, weather forecasts, correct time, train dispatches, stock and market reports, distress (SOS) calls by ships, greetings, and business messages are but a few of

Keystone View Co.

Fig. 441. A Portable Broadcasting Station

The man at the right is speaking into the microphone of the radio sending set, telling thousands of listeners about each play in the World Series baseball game between the New York Giants and the Washington Senators.

the many communications for which electricity is used (Figure 441). How different the activities of our daily life would be without these modern methods of sending messages, and how little you would know of the great world in which you live!

In this unit you will study the ways of sending messages by electricity. If space permitted, we should consider other important methods of communication, such as printing, the mail service, and codes of various kinds. These you may read about in encyclopedias and in other reference books. They will furnish excellent subjects for reading at your leisure.

Before you begin the study of the problems of this unit, you should have a general idea of the different methods of electric

communication. All of these are alike in certain respects. There are four essential parts in every system of sending messages by electricity. First, there must be a source of electric energy, such as the cell or dynamo. Second, some means of carrying the electric current from one place to another is necessary. This may be a set of wires, as in the doorbell or the ordinary telegraph or telephone, or it may be merely space, even a vacuum, as in the wireless or radio. Third, it is necessary to have some device for sending the message, such as the push-button of the doorbell, the key of the telegraph, the transmitter or mouthpiece of the telephone, or the microphone and transmitting apparatus of the wireless. And fourth, there must be some device to receive the message. Thus, a doorbell rings when the push-button is pressed; the telegraph receiver or sounder reproduces the dots and dashes of the sending-key; the telephone receiver reproduces the voice or sounds which set up electric currents in the transmitter; and the receiving set of the radio picks up the waves sent out by the sending station and reproduces the dots and dashes of the sending-key or the sounds which are made before the microphone or telephone in front of which the speaker or singer in the broadcasting station stands.

To summarize, every system of electric communication consists of four essential parts: (1) a source of electric current, (2) material or space for carrying the electric energy, (3) a device to send the energy through the line or space, (4) a device for receiving the energy and changing it to sound waves.

PROBLEM 1: HOW ARE MESSAGES SENT OVER WIRES BY TELEGRAPH?

Since the invention of the early telegraph, shown with its inventor in Figure 440, many improvements have been made. Let us see how the *telegraph* works.

In modern telegraphic communication the operator takes the message from the click of the sounder. Figure 442 shows the instruments and connections necessary for a simple telegraph.

When the *key* is in the circuit with the key switch open, and the lever of the key is pressed down, the current from the battery comes to one binding post of the key, flows through the metal frame to the *contact points*, and then to the other binding post and through the wire to the binding post of the *sounder*. From here it goes around the coil of the *horseshoe electromagnet* and back to the other binding post, and then returns to the cell. As the current passes through the coil, the iron core becomes magnetized and draws the heavy iron *armature*, or bar, downward until it strikes the metal frame, producing a click. When the current is broken at the key by allowing the lever to rise and to separate the contact points, the electromagnet of the sounder loses its magnetism (see Experiment 84, page 404), and a spring on the sounder forces the armature away from the magnet. As it moves upward, it strikes the screw above and produces a faint click. The time between the downward click and the upward click varies as the time during which the contact points of the key are in contact. If the interval is short, it is called a *dot*; if long, it is called a *dash*. These dots and dashes are sent in various combinations to represent letters, numbers, and even entire words or ideas. Such combinations are known as *code*, and they make up code messages.

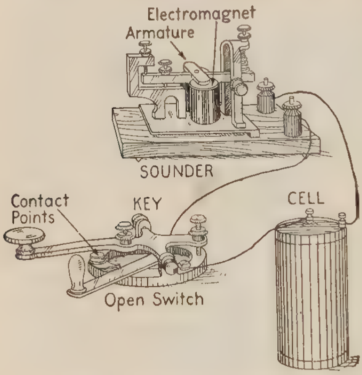


Fig. 442. A Simple Telegraph

The wire from the key goes to one binding post of the sounder, then around the two coils of the electromagnet, and back to the other binding post.

Two systems of code are shown in Table XV. The early code used in this country was known as the American Morse Code. This is still used by land telegraph stations in our country. The International Morse Code, or Continental Code, is used

for land telegraphy in all foreign countries, and by all radio stations the world over. Note that in the American Morse there are spaces between the dots for the letters *C*, *O*, *R*, *Y*, and *Z*. These spaces make sending and receiving very difficult unless the spacing is carefully done at the key by the sender. In the other code only dots and dashes are used. This arrange-

TABLE XV: TELEGRAPH CODES

	American Morse Code	International Morse or Continental Wireless Code		American Morse Code	International Morse or Continental Wireless Code
A....	• —	• —	S....	•••	•••
B....	— •••	— •••	T....	—	—
C....	•• •	— • — •	U....	•• —	•• —
D....	— ••	— ••	V....	••• —	••• —
E....	•	•	W...	• — —	• — —
F....	• — •	•• — •	X....	• — ••	— •• —
G....	— — •	— — •	Y....	•• ••	— • — —
H....	••••	••••	Z....	••• •	— — ••
I....	••	••	1....	• — — •	• — — — —
J....	— • — •	• — — —	2....	•• — ••	•• — — —
K....	— • —	— • —	3....	••• — •	••• — —
L....	——	• — ••	4....	•••• —	•••• —
M...	— —	— —	5....	— — —	•••••
N....	— •	— •	6....	••••••	— ••••
O....	• •	— — —	7....	— — ••	— — •••
P....	•••••	• — — •	8....	— ••••	— — — ••
Q....	•• — •	— — • —	9....	— •• —	— — — — •
R....	• ••	• — •	0....	———	— — — — —
Period	•• — — ••	•• •• ••	Comma...	— • — •	• — • — • —
Interrogation..	— •• — •	•• — — ••	Distress (SOS)	••• •• •••	••• — — — •••

ment makes the work of the operators easier as well as more accurate.

How a simple telegraph works. The simple telegraph system which is used for short distances, and which you can set up with commercial or homemade instruments, can be understood from Experiment 99.

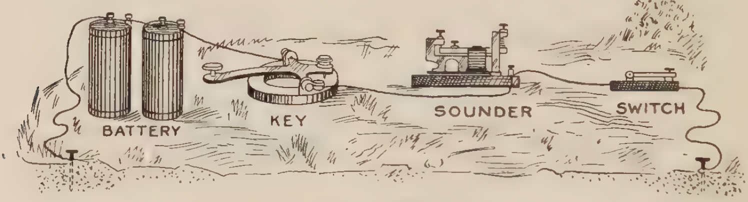


Fig. 443. A One-Wire System

If the ground is very dry, pour a pail of water on each place where the nails are pushed into the soil. Moist earth is a much better conductor than dry soil.

Experiment 99: How can a simple telegraph be set up and operated?

(*a*) Connect a cell, a sending-key, and a sounder as in Figure 442, using two wires to complete the circuit. When you have the proper connections, send in code: "Attention! This is a double-wire system."

(*b*) Take the cell, wire, key, sounder, and two long nails out in the yard. Set up the telegraph, using only one wire between the sounder and key and using the earth to complete the circuit, by sticking the nails in the earth as in Figure 443. Send by code: "The earth is a conductor of electricity," and "This is a one-wire system."

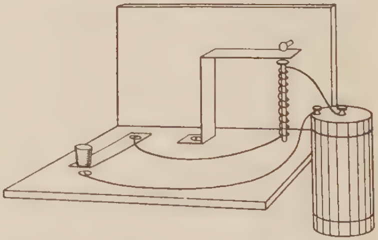


Fig. 444. A Homemade Telegraph

The key is a strip of brass or iron to which a cork is fastened. The sounder is a bent strip of soft iron. There should be many turns of wire around the nail.

(NOTE: If you do not have a commercial key and sounder, make a crude instrument as shown in Figure 444.)

The telegraph system between two stations requires a key and a sounder in each station. The arrangement for short distances is shown in Figure 445. A cell, or battery of cells, furnishes the electric current. The switches on the keys are kept closed. When an operator at Station A wishes to send a message to B, he opens his key switch, sends the call signal to B, and then closes his key switch. Station B then opens his switch, signals A to send the message, and closes his switch to receive A's message.

Exercise 1. Explain why the switches must be opened and closed as described in the preceding paragraph.

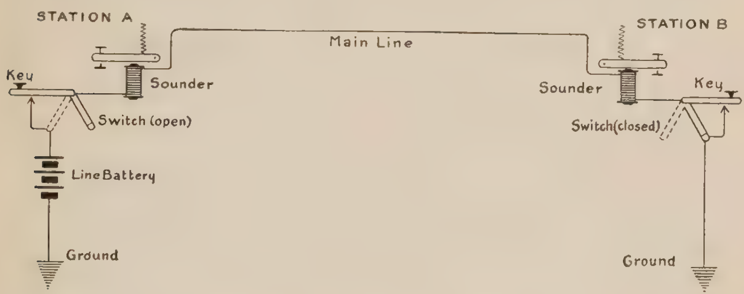


Fig. 445. A Telegraph System

The important instruments are represented by symbols. Compare the symbols with the instruments in Figures 442 and 443.

Experiment 100: How can you set up a telegraph line between two stations?

With two cells, two keys, two sounders, and the necessary wire set up a telegraph system between two rooms or between two houses. You can use two wires, or one wire and the ground, to complete the circuit. Attaching the ground wire to a gas pipe or water pipe will serve as a ground or earth connection.

Relays are necessary in a long-distance set. For long-distance communication the simple set which you have just made will not work. The resistance of the long wire to the flow of electricity is so great that a few cells cannot send enough current to operate the sounder. To overcome this difficulty, the *relay* is used in each station, and the connections are made as in

Figure 446. The relay (Figure 447) has an electromagnet made with many turns of wire, and an armature which is very easily moved. The slightest current will, therefore, cause enough

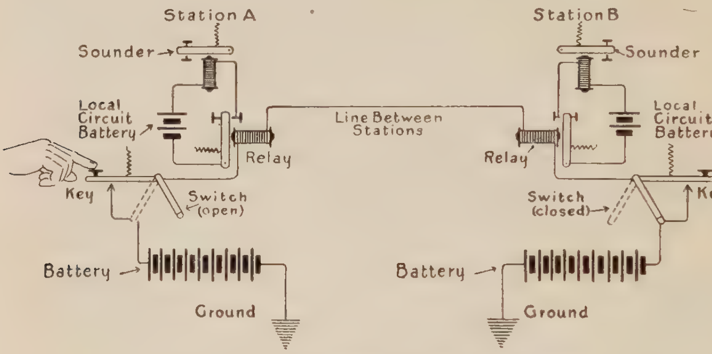


Fig. 446. A Long-Distance Telegraph System

There are three electric circuits in such a system. One is the line circuit composed of the batteries, keys, the coils of the relays, the line between stations, and the earth. The other two are the local circuits in the telegraph stations, each composed of the battery, the sounder, the relay armature, and the necessary wire.

magnetism to pull the armature and close the local circuit, made up of a cell, a sounder, and the relay armature. The battery of the local circuit then operates the sounder whenever the local circuit is opened and closed by the relay armature. You can now examine the figure and see how the arrangement works. In Figure 446 the operator at Station *A* is ready to send a message to Station *B*. How can you tell that this is true?

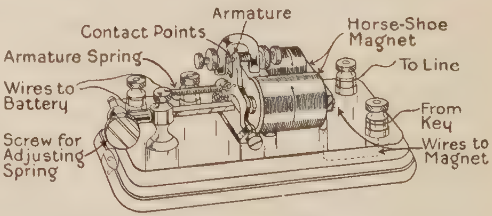


Fig. 447. A Relay

Exercise 2. What is the use of each part of a telegraph system?

Exercise 3. Does the relay strengthen the local circuit? Explain your answer.

Exercise 4. Why are the wires "grounded" at the local stations?

PROBLEM 2: HOW DO THE ELECTRIC BELL AND ELECTRIC BUZZER WORK?

The electric bell and buzzer save man many steps. By merely pressing a push-button one may ring a bell or sound a buzzer, calling for service or announcing one's presence. A single push-button may be used to ring several bells, or a single bell may be rung by any one of a number of push-buttons located in different parts of the building. There are hundreds of uses of these simple methods of communication.

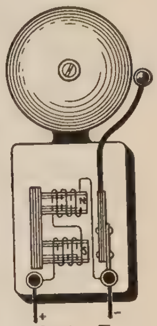


Fig. 448 A Single-Stroke Bell

The simplest bell is a *single-stroke bell* (Figure 448). When the circuit is closed by pressing the push-button, the current flows through the electromagnet, which immediately draws the armature to the magnet, causing the clapper attached to the armature to strike the bell. The armature remains in contact with the core of the magnet so long as the bush-button closes the circuit. The spring of the clapper is so arranged that the clapper does not remain in contact with the bell and thus deaden the sound. See if you can trace the current through the bell in the figure. Note that the wires on the two arms of the horseshoe magnet are wound in opposite directions. This makes one pole a north pole and the other a south pole, as indicated by the "N" and "S" on the poles of the magnet in Figure 448.

The ordinary doorbell rings intermittently. The common doorbell is so arranged that the clapper strikes the bell several times a second when one presses the button to ring the bell. Experiment 101, on the next page, shows how the electric current operates such a bell.

Experiment 101: How does the current pass through a doorbell?

Connect a cell, push-button, and ordinary doorbell as in Figure 449, and trace the current through the circuit, starting at the negative pole of the battery and going through the push-button to the bell. (The metal of the base of the bell is a conductor.)

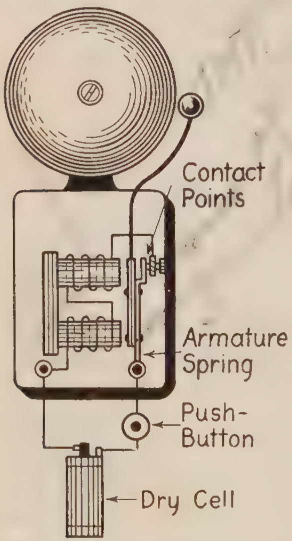


Fig. 449. An Ordinary Doorbell
The dry cell and push-button are shown diagrammatically much smaller in proportion than they really are.

When the circuit is closed by the push-button, the current flows through the coil and magnetizes the electromagnet. The armature is drawn over, and the clapper strikes the bell. As the armature moves, the *armature spring* separates the contact points, and no current can flow. The electromagnet loses its magnetism, and the armature spring forces the armature back to its original position. This closes the circuit again, and the operation is repeated. The rapid closing and opening of the circuit cause the clapper to *vibrate* as long as the push-button is held down.

The electric buzzer acts like the doorbell. Since there is no bell in the buzzer device, the rapid vibration of the armature causes the buzzing sound. The speed of the vibration can be controlled by changing the distance between the contact points. If this distance is great, more time is required for the vibrator to move, and it vibrates less rapidly, causing a low pitch, or note; if the distance is small, the buzzer has a high pitch.

Exercise 5. Examine your doorbell at home to see if it is like the one described. If it is not, how does your bell work?

Exercise 6. A core of soft iron in an electromagnet becomes magnetized quickly, but loses its magnetism as soon as the electric current stops flowing. Steel holds its magnetism when once magnetized. Would you use soft iron or steel for the core in an electromagnet?

PROBLEM 3: HOW DOES A SIMPLE TELEPHONE OPERATE?

How can the voice be sent over the telephone? The answer is, "It cannot." How, then, can you hear the person at the other end of the line talk? To answer this you must know what the voice is, and how the different instruments of the telephone can reproduce it.

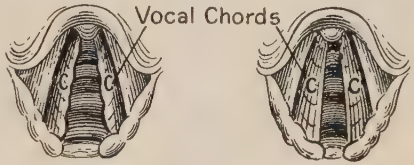


Fig. 450. The Vocal Chords

In the view at the left the chords are not stretched; the right view shows how the chords are pulled tight when one speaks or sings.

The vibrations of your vocal chords produce sounds. If you could see inside your voice box, or *larynx*, which is located near the top of the windpipe leading from the lungs to the mouth, you would notice two chords of strong tissue (Figure 450). These are called the *vocal chords* and are controlled by muscles. When they are stretched, and the air from the lungs is forced through them, they vibrate and cause sound waves to be set up in the air.

Experiment 102: How is sound produced?

(*a*) Strike a tuning-fork on the table. Hold it near your ear. Now look at it closely and observe that the prongs look hazy because they are vibrating rapidly. Strike it again and lower it into a glass of water until it touches the water (Figure 451). What happens?

Fig. 451

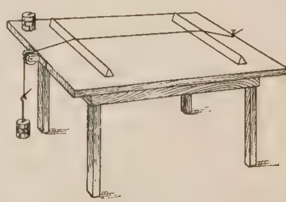


Fig. 452. Apparatus for Experiment 102

(*b*) Stretch a short wire tightly (Figure 452). Pick or snap the wire at one end. Does the vibrating wire produce sound? Can you see and hear the wire vibrate after picking it? Add more weights to the free end of the wire and try again. Result?

The vibration of a string or a tuning fork produces sound. You can understand then how the vocal cords produce sound when they vibrate.

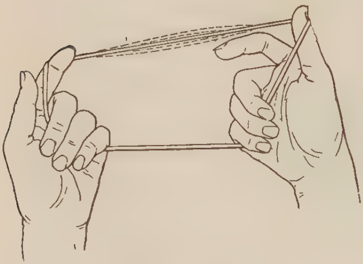


Fig. 453. A Vibrating Rubber Band

The *pitch* of the sound depends upon how rapidly the cords vibrate. If you stretch a rubber band (Figure 453) and pick it, a sound of a certain pitch is produced; if you stretch the band more tightly, the pitch is higher. In the same way the vocal chords may be stretched tightly, and the air from the lungs then sets them in rapid vibration, causing a high note. Or they may be less tightly stretched, and will then produce a lower note. The shape of throat and mouth and the position of tongue and teeth make a difference in the *quality*, or tone, of the sound, but the rate of vibration of the vocal chords determines the pitch.

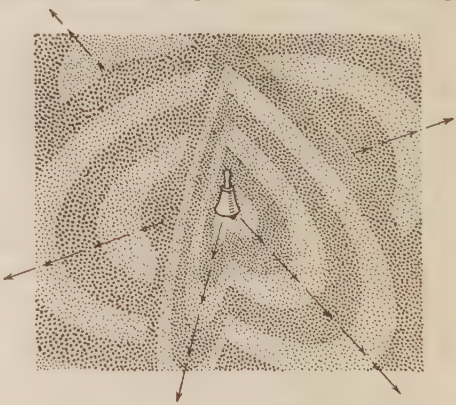


Fig. 454. Sound Waves

As the bell vibrates, it causes the air molecules to move outward in all directions. This sets up waves in the air and produces alternate thick and thin layers of air molecules in all directions around the bell. The drawing shows these waves in only a few planes of the sphere. By holding the page at arm's length you can see the planes of the sphere more distinctly.

Sound travels in all directions. If you could see the waves of the air produced by sound, they would look something like the waves in Figure 454. They travel in all directions from any vibrating object. These air waves may strike a body and cause it to vibrate.

Experiment 103: Can air waves cause a body to vibrate?

(*a*) Strike one tuning-fork on the table and quickly hold it near another tuning-fork of the same pitch. Bring the second tuning-fork to your ear, and you find that it is now vibrating. The vibrations of the first fork set up air vibrations which in turn caused the second fork to vibrate. (You can do the same experiment by using two stretched wires having the same pitch.)

Fig. 455. Experiment 103

(*b*) Get the pitch of a certain piano string. Then sing loudly the syllable *O*, in the same pitch, while the loud pedal of the piano is being pressed down so that the string is free to vibrate (Figure 455). Now stop singing and you can hear the string vibrate. (You can do this with any stringed instrument.)

Sound waves make the telephone possible. The simplest form of telephone is shown in Figure 456. The mouthpiece, or *transmitter*, is connected to a cell and a receiver. When someone speaks into the transmitter, the air waves cause a thin membrane in the transmitter to vibrate. This vibration of the membrane causes the electric current which flows from the cell and through the coil of the electromagnet in the *receiver* rapidly to increase and decrease in strength. This, in turn, rapidly changes the attraction of the magnet for an iron membrane in the receiver, and causes the membrane to vibrate. The vibrating membrane sets up sound waves in the air around the receiver exactly like those caused by the speaker's voice. The air waves strike the listener's ear (Figure 456), and he hears the speaker's words.

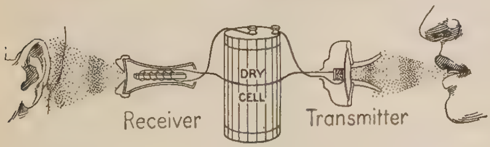


Fig. 456. A Simple Telephone

Sounds do not travel along the wire. They cause a change in the electric current which flows through the receiver. This sets up sound waves around the receiver.

Now let us see more fully how the different parts of the ordinary telephone work. Figure 457 shows the various necessary instruments and connections of a telephone between two stations. At each station there are a battery, a transmitter, an *induction coil* or transformer, and a receiver. Note that the transmitter, battery, and *primary coil* make one circuit at each station, and that the receivers and the *secondary coils* of the *induction coils* are all on one circuit separate from the transmitter circuits.

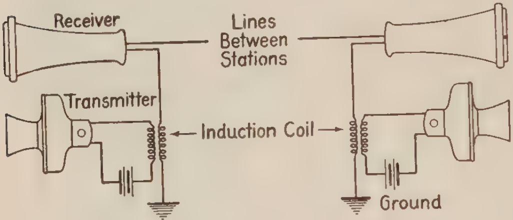


Fig. 457. Station Telephone System

The line between stations goes through the central telephone exchange. In the telephone the primary coil is inside the secondary coil of the transformer

The telephone transmitter changes sound to electric energy. The transmitter is constructed as shown in Figure 458. The current from the local battery flows to the metal disc, or *diaphragm*, then through the carbon particles in the little cylindrical box which is made of a non-conducting material, to the metal back of the transmitter, and then through the primary coil of the induction coil and back to the battery.

When someone speaks into the transmitter, the vocal chords set up sound waves in the air (Figure 456), which strike the diaphragm and make it vibrate, just as the piano string in Experiment 103 was set in vibration by the voice. The diaphragm is so sensitive that it vibrates according to the pitch and the quality of the sound. Since the carbon particles rest against the diaphragm, the vibration increases and decreases the pressure between the carbon particles. The current which flows through the transmitter varies according to the pressure, for, when the pressure is greater and the particles are in closer contact, the resistance is decreased and more current can flow through them. When the pressure is less and the contact between the particles is not so great, less current can flow.

The sound waves cause the current in the transmitter circuit to vary in strength because of the vibration of the diaphragm. The primary coil therefore rapidly changes in its magnetic power as the current through it changes. Thus, lines of magnetic force move outward as the magnetism increases and inward when the magnetism decreases. These rapid changes in the lines of force which pass over the secondary coil, first in one direction and then in the other, cause an alternating electric current to flow in the secondary coil. Since there are many turns of wire in the secondary coil, the force, or voltage, of the electric current produced therein is greater than that in the primary coil. This greater force can then send the electric current through the wire to the receiver miles away. However, the force of the current in the secondary-coil circuit varies in strength on account of the varying strength of the transmitter current. This varying current flows through the line to the receiver.

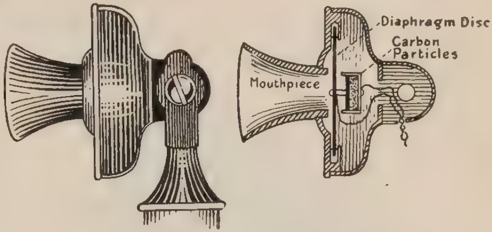


Fig. 458. The Transmitter

The inside construction of the receiver is shown at the right. The wires lead to the battery and to the receiver.

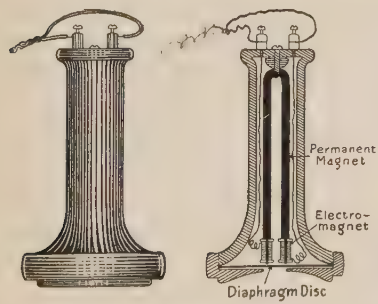


Fig. 459. The Receiver

The diaphragm disc is made of soft iron. Why?

The receiver changes electric energy to sound. The receiver of the ordinary telephone consists of a bar or horseshoe magnet, one or two coils of wire, and a thin iron disc which is held in a hard rubber case so that it cannot touch the magnet (Figure 459). If a horseshoe magnet is used, the coils must

be wrapped in opposite directions. (See page 455.) When the varying electric current sent out by the transmitter and the secondary coil passes through these electromagnetic coils, the iron receiver disc is attracted by the rapidly changing magnetic attraction and is caused to vibrate exactly as the metal diaphragm in the transmitter vibrates. The vibration of the receiver disc sets up air waves exactly like those from the vocal chords of the speaker at the transmitter end.

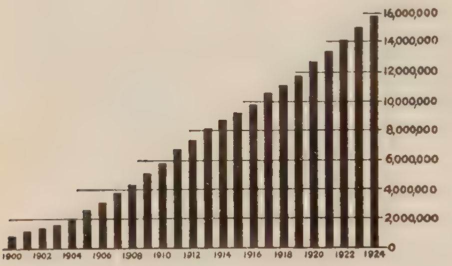


Fig. 460. Growth of Telephones

From less than a million telephones in 1900 the number has grown to nearly 16,000,000 in 1924.

The whole story retold. You can now understand the ordinary telephone. Let us summarize the important points. The transmitter speaking-tube receives the sound waves of the air set up by the vocal cords; the diaphragm in the transmitter vibrates; the vibrating diaphragm causes changes of pressure on the carbon particles; the changes of pressure cause the changes in the electric current through the primary coil of the induction coil; the variation of the current in the primary coil increases and decreases the current of greater force set up in the secondary coil; the varying current in the secondary coil and line causes differences in the strength of the magnetism in the coil around the magnet in the receiver; this increases and decreases the pull of the permanent magnet on the disc of the receiver; the receiver disc vibrates exactly as the transmitter diaphragm vibrates; these vibrations start air waves like those of the speaker's voice; these air waves strike our ear and produce a sound like the speaker's voice.

The telephone with a modern central station is much like the telephone described, but the battery or dynamo used to

send the current is located in the central office. The central station is a very complicated apparatus, especially in large cities. If you have an opportunity to visit such a station, be sure to do so, and have the manager explain to you how it works.

The growth of the telephone industry in our country has been enormous. Figure 460 gives you some idea of the increase in the number of telephones used in our country since 1900. Today, about 16,000,000 telephones are in use in the United States. This is nearly two-thirds of all telephones in the world. In 1923 there were about 53,000 separate telephone systems in the United States, employing over 325,000 men and women. Twenty-nine million, seven hundred thousand miles of wire were necessary to connect the telephones, and over 20,000,000,000 conversations, or calls, were completed. Figure 461 shows the percentage of these calls for the different hours of the day.

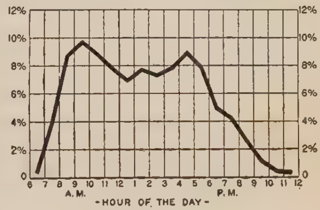


Fig. 461. Percentage of Telephone Calls at Different Hours of the Day

For example, 8 per cent of all calls are made between 11 and 12 o'clock in the forenoon.

Exercise 7. Explain why the diaphragm disc of a receiver must be made of soft iron, but the diaphragm of the transmitter is not made of iron.

Exercise 8. Write a short story in which you explain the first two sentences following the title of Problem 3.

PROBLEM 4: HOW ARE WIRELESS MESSAGES SENT?

Samuel F. B. Morse and Alexander Graham Bell are men who will always remain famous for their great inventions. Guglielmo Marconi, an Italian scientist, is, however, equally famous. In 1896, Marconi, a young man of 21 years, sent a message without the use of wires over a distance of two miles. While other men had proved that wireless messages were possible, Marconi made such important improvements in this

field that he must be given credit for his great inventions. Since that time many improvements have been made on the radio sending and receiving devices. Today millions of receiving sets are in use in our country, taking from space the messages, speeches, and music sent out by the thousands of sending sets. Hundreds of "broadcasting stations" add to the education and enjoyment of those who are fortunate enough to be able to build or purchase receiving sets, and who know how to "tune in" on the various sending stations.

Electric energy travels as particles and waves. To begin our understanding of radio, or wireless telegraphy and telephony, let us see how electricity travels from one place to another. Any wire or conductor contains millions of small particles of electricity, or *electrons*. When these electrons are set in motion along the wire, we say the current is flowing. When the wire is attached to a cell or a dynamo, these so-called "generators" of electricity force the electrons to move, much as a pump forces water through a pipe. Thus by means of a key or a push-button we can complete a circuit, and the cell or dynamo which is connected in the circuit will pump electrons along the wire. At any point along the wire electrons will then be moving, and we have an electric current.

In radio there are no conductors or wires to carry the current from the sending set to the receiving set. It is not well understood how this transmission takes place, but you can imagine something like this: The sending set sends out *waves of electric energy* similar to the magnetic lines of force around an electromagnet. These electric waves travel outward from the sending station in all directions. They travel through space in much the same way that waves move outward along the surface of water when a stone is thrown into a pond. There is one important difference, however, between water waves and radio waves: the former move outward in circles, while the latter move outward in spheres. That is, radio waves move in all directions from the sending set, just as sound waves move in all directions from a bell. (See page 458.) How these electric

waves are set in motion through space you will understand better by examining a simple sending set.

A simple buzzer sending set is easily made. A simple sending set like that shown in Figure 462 may be used to send wireless messages over short distances. The set consists of a few electric cells, a key, an induction coil with a *vibrator*, an *aerial*, and a *spark-gap*. If you examine the figure carefully, you will see that the cells are connected in circuit with the key, the vibrator of the induction coil, and the inner coil of the induction coil. Note that the induction coil consists of two coils. The inner one has a few turns of heavy insulated wire. It is called the primary coil because it is connected with the battery. The outer coil consists of many turns of fine insulated wire. This is the secondary coil. It is connected with the spark-gap, the aerial, and the ground. The wires of the primary and secondary coils are not in the same circuit.

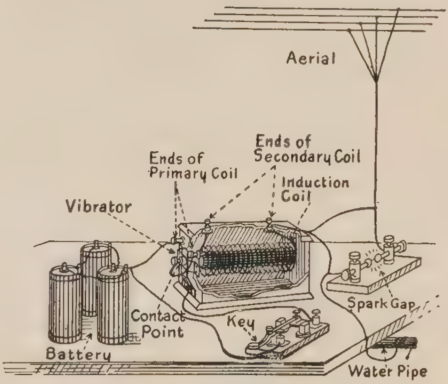


Fig. 462. A Buzzer Sending Set

If an induction coil is available, examine it to see how it works.

The primary circuit induces a current in the secondary coil. When the key is closed, the cells are connected in the circuit and force electrons through the key, wire, vibrator, contact point, primary coil, and the wire leading back to the cells. As soon as these electrons move in the primary coil, it becomes a magnet. The soft iron core of the magnet increases the magnetism of the coil. The vibrator, being made of iron, is attracted to the core. This separates the vibrator from the contact point, breaking the circuit. No current can now flow, and the electromagnet at once loses its magnetism. The spring of the vibrator

forces the vibrator back against the contact point, making the circuit once more. Immediately electrons start to flow again, since the cells are now connected in the circuit. The primary coil and core are again magnetized, and the vibrator is again pulled over, breaking the circuit. Thus the vibrator moves back and forth between the contact point and core, making and breaking the circuit many times each second.

The sudden making of the primary circuit by the vibrator causes electrons to start moving and to flow rapidly through the wires of the primary coil for a moment. Then, the sudden breaking of the circuit immediately cuts off the cell (the pump), and the electrons slow down and stop. As the electrons start to move, they cause magnetic lines of force to move outward from the primary coil across the wires of the secondary coil. These magnetic lines of force cause the millions of electrons in the wires of the secondary coil to start moving, thus causing a current to flow in the secondary coil. Because there are many turns of wire in the secondary coil and because the magnetic lines of force come outward at such great speed, the electrons in the secondary wire are set in motion with great force. This produces a current with a high voltage. (See page 461.)

At the breaking of the primary circuit, the electrons in this circuit slow down and stop. The magnetic lines of force now move inward toward the primary coil across the secondary coil wires. Thus they cut across these wires in the opposite direction from that during the making of the primary circuit. This causes the electrons in the secondary coil to reverse their direction. You can see, then, that the current in the secondary coil flows in one direction one moment and in the reverse direction the next moment. The alternating current thus set up, or *induced*, in the secondary coil has a much higher voltage, or force, than the current in the primary circuit, and alternates very rapidly because of the rapid making and breaking of the primary circuit by the vibrator.

The secondary circuit sends out waves of electric energy. Now if you examine Figure 462 again, you will see that this

secondary coil is connected to the spark-gap, and that one ball of the spark-gap is connected to the aerial while the other is connected to the earth by means of the water pipe. The high voltage of the current set up in the secondary coil causes the electrons to leap across the spark-gap at a tremendous speed, producing sparks like lightning. (Since the voltage is so high, one should be careful not to place the hand near the induction coil or spark-gap while the spark is passing.)

The sparks leap back and forth at such tremendous rate that the electrons in the aerial, the ground wire, and secondary coil are caused to alternate their direction millions of times a second. We say the current *oscillates at high frequency*, meaning that the direction of the current changes many, many times a second. Such rapid movement of the electrons in the aerial sets up waves in the space around the aerial. These waves then move outward across space. The distance which they travel depends upon the voltage of the secondary circuit and the atmospheric conditions.

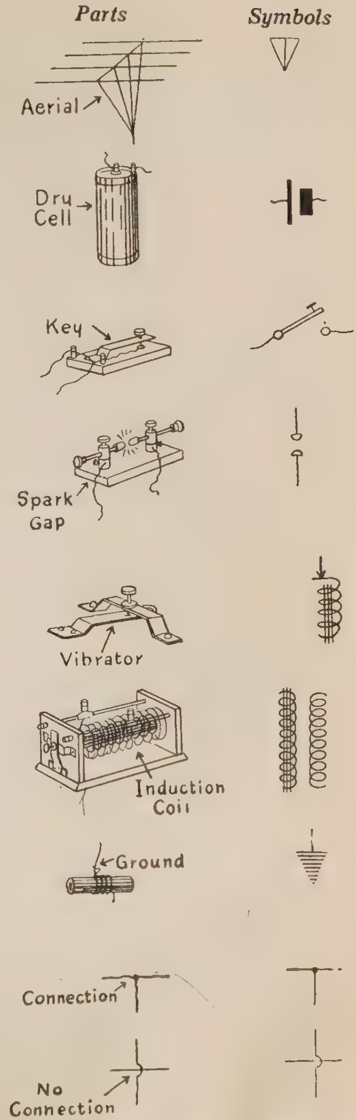


Fig. 463. Radio Parts and Symbols

Since the waves are set up only when the key is pressed down, or closed, it is possible to send out the waves for short or long intervals, like the dots and dashes of a telegraph code. The waves of short and long intervals may be detected, or "picked up," by a receiving set and heard as short or long buzzes in the head phones. The message sent with the key may, therefore, be understood by anyone who knows the code.

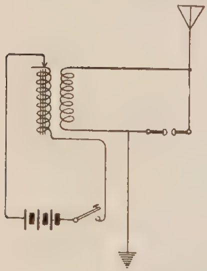


Fig. 464. "Hook-up" for Figure 462

There are many different kinds of sending sets. The sending sets for the radio-telephone used in broadcasting stations are far too complicated to study here. It is enough for us to know that they send out waves through space. The waves are, however, changed somewhat by the voice or music which enters the transmitter of the telephone connected to the sending set. (See Figure 456, page 459.) The sounds in the sending station strike the telephone transmitter membrane, or transmitter, and change the radio waves in much the same way that sound changes the electric current in the ordinary telephone. Because different stations send waves of different lengths, it is necessary for us to "tune" our receiving sets so that we may be able to listen to the station which we wish to hear. Then our set can reproduce the changes in the waves caused by the voice or music at the broadcasting station, and we can enjoy the speech or concert.

Exercise 9. Make a statement summary of everything that happens when the key of the simple sending set is closed.

Exercise 10. Each instrument of the sending set described is shown in Figure 463, and opposite each is the symbol which radio men use to represent the instrument. Figure 464 shows a diagram, or "hook-up," of the set as represented by radio experts. Copy the "hook-up" and label each part. Below your drawing list the name of each part, and following each name state briefly the use of the part. Also, label the primary and secondary circuits.

PROBLEM 5: HOW DO SIMPLE RADIO RECEIVING SETS WORK?

A very simple set will receive code messages. One of the simplest receiving sets with which you may hear code messages like those described in Problem 4 is shown in Figure 465. It consists of an aerial, a *crystal detector*, a pair of *head phones* or a telephone receiver, and the necessary connections. If such a set is "hooked up" in a room adjoining the room in which a sending set like that described in Problem 4 is located, messages sent out by the sending set may be heard.

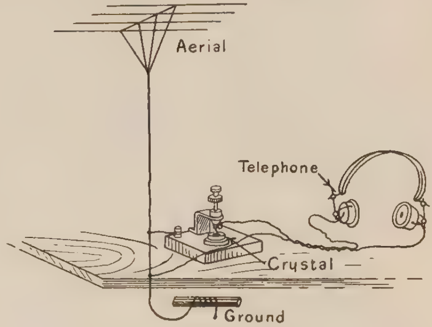


Fig. 465. A Crystal Set

The necessary parts can be obtained at any radio store.

This simple receiving set is easily set up. The aerial is either insulated or bare copper wire stretched across the room. Number 18 or Number 20 wire will serve. One end of the wire is left free; the other is attached to a water pipe. The head phones or receiver should have a resistance of more than 1000 ohms. The crystal detector and the phones are connected to the aerial wire as shown in the figure. The *crystal* is made of a mineral called galena. Directly above the crystal is a small wire which completes the circuit through the crystal detector when it touches the crystal. It may be necessary to shift the wire until it touches a certain part of the crystal before a signal can be heard in the phones. This part of the crystal is commonly called the "sensitive spot."

Let us see how this set works. You remember that the waves of electric energy which come through space from the sending set are caused by "high-frequency oscillations," or very rapid alternations of the electrons in the aerial of the sending set.

Now when these waves strike the aerial of the receiving set, the action is reversed. They set the electrons in the aerial wire into very rapid oscillations. This causes oscillations all along the wire.

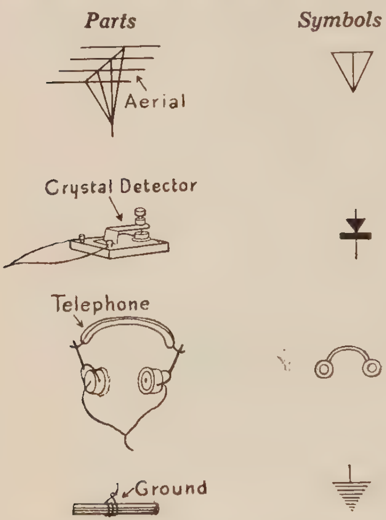


Fig. 466. Parts and Symbols of a Simple Crystal Set

Some electrons would oscillate in the branch circuit in which the crystal detector and phones are connected, except for the fact that such high-frequency alternations cannot pass through coils like those inside the phones. Moreover, the crystal has the property of allowing a current to pass through in one direction only. This direct current can flow through the phones. Since this current through the phones varies in strength because of the waves which strike the aerial, it causes the diaphragm of the head phones to vibrate, producing a buzz-like noise. The length of each buzz corresponds to the interval during which the key at the sending set is closed. Thus, short and long buzzes may be sent and received as a code message.

To "listen in" to a message from the sending set described in Problem 4, have someone operate the key of the sending set in an adjoining room. Place the head phones of the receiving set on your head, and then move the wire about on the surface of the crystal until you find a "sensitive spot," when the buzzes will be heard distinctly.

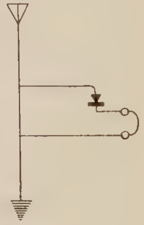


Fig. 467

You may also "pick up" code messages from distant sending stations with this simple receiving set.

Exercise 11. The symbols for the parts of the simple receiving set are shown in Figure 466. The "hook-up" for this set (Figure 467) shows how radio men represent the set in a diagram. Copy the "hook-up," and neatly label each part. Below your drawing explain briefly how the set works.

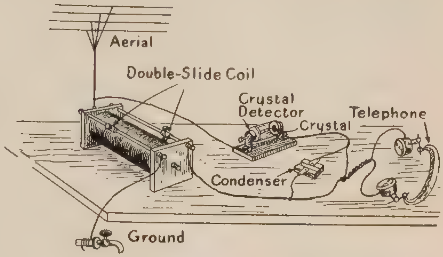


Fig. 468. A Double-Slide Tuning-Coil Crystal Receiving Set

The aerial wire and the wire which leads to the crystal detector are connected to one end of the coil. The ground wire and the wire which comes from the phones and condenser are attached to the ends of the rods on which the slides move.

A coil crystal-detector set is more satisfactory. For receiving code and wireless telephone conversations, reports, and musical concerts sent out by amateur and commercial sending stations, the crystal-detector set is combined with a coil. A coil crystal-detector set is shown in Figure 468. With this set it is possible to receive code or telephone messages from stations within a few miles, and to listen to one station without hearing other stations at the same time. The set consists of an aerial, a coil (called a "double-slide tuning-coil"), a ground wire, a condenser, a crystal detector, and head phones. The aerial may be placed in the house or outside, or bed springs may be used as an aerial if the sending station is a powerful one and is only a few miles away. If the aerial is placed outside the house, a *lightning arrester* should be used to prevent the danger of fire. The parts for the coil may be purchased at a radio store, and the coil can be wound, or the entire coil may be bought. Figure 468 shows how to make the connections.

In order to listen to a broadcasting or code-sending station, the receiving set must be "tuned"; that is, it must be properly adjusted. The wire of the crystal detector must be on a sensitive spot, and the slides must be moved until they are in the correct

position and the message is clearly heard in the head phones. The "tuning in" on any station may require considerable patience at the first attempt. Thereafter it is easy to do, since the positions of the slides for a certain sending station change but little from time to time.

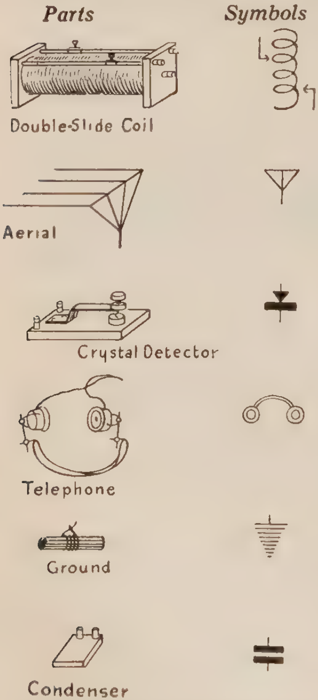


Fig. 469. Parts and Symbols of a Double-slide Tuning-Coil Crystal Set

Note that there are two circuits. The *aerial circuit* consists of the aerial, some turns of the tuning coil, one of the slides, and the ground wire. This is known as the *primary circuit*. The detector circuit, often called the *secondary circuit*, consists of (1) a wire leading from the post of the coil to which the aerial is connected, (2) the crystal detector, (3) the phones, (4) a wire leading to the other slide, and (5) some turns of the coil. A condenser is connected across this secondary circuit from one side of the phones to the other.

The operation of the set is simple. When the waves from the sending station strike the aerial, oscillations are set up in the primary circuit, provided the slide contact in this circuit is properly set. These oscillations cause similar oscillations in the part of the coil which is in the secondary circuit, if the slide contact in this circuit is in the correct position, but the crystal allows the electrons to flow through it in one direction only. Thus, if you have properly tuned in on a code-sending set, a varying direct current passes through the crystal and phones and causes the diaphragms in the head phones to vibrate and send out buzzes. Or, if the sending

set is a telephone sending station, the diaphragms vibrate just as the membrane in the transmitter at the sending station vibrates, and you hear the speech or the music.

Exercise 12. Figure 469 shows the symbols for the instruments in the coil crystal-detector set. Draw a "hook-up" of the set, using the symbols, and label the parts.

PROBLEM 6: HOW IS A SIMPLE VACUUM-TUBE RECEIVING SET OPERATED?

The *vacuum-tube receiver* (Figure 470) is more commonly used than the sets previously described. It has three important

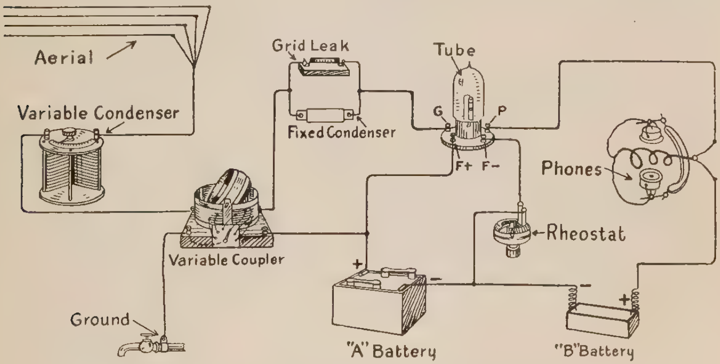


Fig. 470. A Simple Vacuum-Tube Receiving Set

For experimenting with radio sets like this one it is best to keep the parts arranged like this. Various "hook-ups" can thus be made with little trouble. This "hook-up" is called a non-regenerative set.

advantages over simpler and less expensive crystal sets. First, sending stations at a greater distance may be heard. Second, the sounds in the sending station are reproduced much more loudly. Third, it tunes better, making it possible to "tune in" any sending station without so much *interference* from other stations. It is therefore more *selective* than the crystal receiving set.

All of the parts for this set may be purchased at any radio store. If a three-cell storage battery is used as the *A* battery, a

six-volt tube is needed; if the *A* battery is a dry cell, a one-and-one-half-volt tube is used; if the *A* battery consists of three dry cells connected in series, it will operate a 4.5-volt tube. The *B* battery has a voltage of 22.5 volts. The radio dealer will know the kind of instruments necessary to make the set.

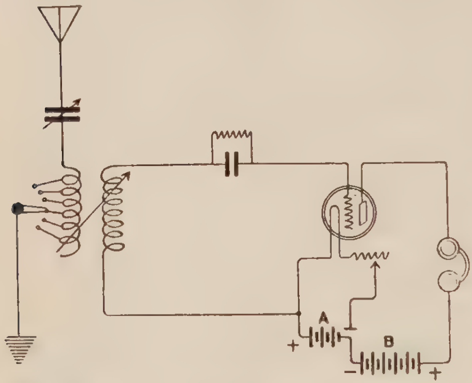


Fig. 471. "Hook-up" for Figure 470

To operate the set, the rheostat is turned until the filament in the vacuum tube glows. The head phones are placed in position. The little switch arm connecting the ground wire to the taps is turned so that the end of the arm rests on one of the taps. Then the dials of the variable condenser and of the inside coil of the variable coupler

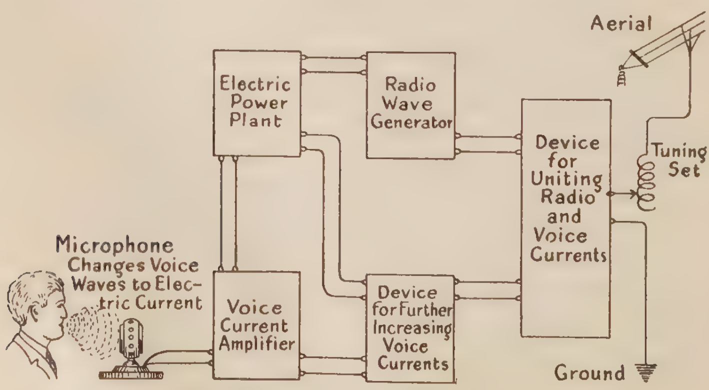


Fig. 472. A Broadcasting Set

are turned to different positions. If no sending station is heard during this operation, the small arm is turned to another tap, and the moving of the dials is repeated. With a little patience and perseverance a station may be detected, although it may be necessary to move the rheostat to a different position and repeat the other operations. The best way to learn how to operate the set, once it is properly connected as shown in the figure, is patiently to turn to various positions the knobs or dials of the rheostat, the variable condenser, the switch arm, and the variable coupler. Once a station is heard, it can always be found again if you remember the position of the dials. If you operate a radio set, keep a record, or *log*, of the position of each dial for the various stations.

How the set works is not easy to explain. It would require many pages to tell the whole story. Anyone who is interested can find sets like this described in simple books on the subject of radio.

Exercise 13. Copy the "hook-up" of the vacuum-tube set (Figure 471) and compare it with Figure 468. Label the parts of your drawing.

Exercise 14. Examine Figures 472 and 473, which will show you the principal parts of a broadcasting station and of a modern receiving set.

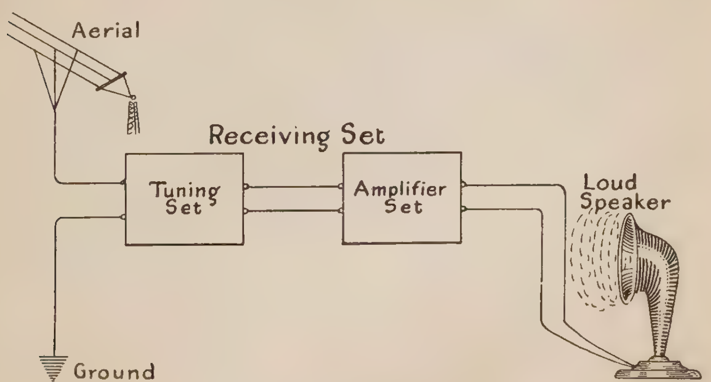


Fig. 473. A Receiving Set

The loud speaker contains coils and a magnet similar to those in a telephone receiver. The horn directs and magnifies the sound waves.

Review Exercise on Unit XVI. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit XVI and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT XVI

1. What advantage do you see in the attempts to combine wireless and wire telephone systems, using wireless central stations?

2. Could you use a bar magnet in an electric bell? Explain.

3. Of what kind of material is the disc, or diaphragm, of a receiver made? Why?

4. Can a telephone transmitter be used as a receiver? Can a receiver be used as a transmitter? Explain.

5. Two wires are used in city telephone circuits, while only one wire is used for country lines. Why is this so?

6. Make a drawing to show the magnetic lines of force around the magnet and disc of a receiver used as a transmitter in the simple telephone described in the text, and explain how alternating currents are set up in the wire by sound waves.

7. What are three ways to increase the strength of an electromagnet?

8. What would be the effect of wrapping the coils of an electromagnet in the same direction? Try it, and explain the results.

9. Bring your radio set to school and explain to the class how it works.

10. Why is a variable-coupler tuner more selective than a double-slide tuning-coil set? (See Figures 470 and 468.)

11. In a radio set, the *B* battery should never be connected to the filament. Why?

12. Learn to send and receive a code message by telegraph.

UNIT XVII

TRANSPORTATION BY LAND, WATER, AND AIR

Preliminary Exercises

1. Name as many different kinds of boats as you can. What are the characteristics which distinguish each kind from the others?

2. What is the chief difference between materials which float in water and materials which sink?

3. Why are canoes more easily overturned than row boats?

4. What kind of machine is an oar? A canoe paddle?

5. What are the kinds of power used to propel boats?

6. What are the differences between an ordinary balloon and a dirigible balloon?

7. How does a kite differ from an airplane?

8. What is the difference between a monoplane and a biplane?

9. What is a hydroplane?

10. Why do airplanes have wheels or pontoons?

THE STORY OF UNIT XVII

If you compare life today with life one hundred years ago, you realize that our present mode of living is possible only as the result of a speedier and more dependable method of transportation. What today are considered the necessities of life were regarded then as luxuries because of the time and the expense involved in obtaining them. Your clothing, your food, and your home present ample evidence of the value of transportation. You eat oranges from California, dates from Egypt, nuts from Brazil, wheat from Kansas, and cheese from New York. Your clothing may have grown on a sheep's back in Australia. Your house may be constructed of lumber from Michigan, stone from Iowa, and glass from West Virginia, and furnished with materials which have come from all parts of the world. This has been made possible by the development of

land and water transportation. What changes a dependable system of air transportation will bring cannot be predicted.

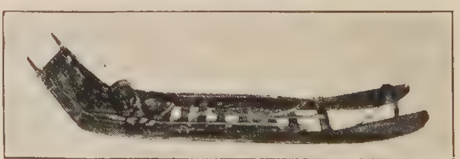
Not only has transportation permitted the exchange of raw and manufactured products, but it has also enabled people to travel. This has resulted in exploration, colonization of new lands, development of new regions, and in a general mingling of the earth's population. Our communities are made up of people from all quarters of the globe. The members of the community are constantly traveling from one place to another, bringing back new ideas and ways of doing things. Transportation has thus enabled one part of the world to learn what the other part is doing and thinking, and has assisted to a great extent in the development of our present progressive civilization.

Underwood and Underwood

Fig. 474. A Primitive Method of Travel

This method of transportation is still in use. The view shown here comes from the Blackfeet Indians of the Glacier National Park region.

Our present system of land transportation did not develop in a single day. It is the product of thousands of years of thinking and work. For centuries man traveled from place to place under his own power and in addition carried his burdens. Later he domesticated, or tamed, the horse, elephant, camel, and ox and packed his load upon their backs, or rode the animals himself. The first

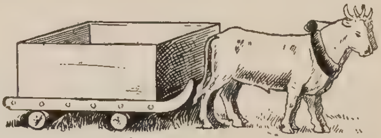


Courtesy American Museum of Natural History

Fig. 475. A Sledge Which Went to the North Pole

This sledge, pulled by dogs, went with Peary to the North Pole.

step in the development of the vehicle was probably a sledge or drag which was pulled along (Figures 474 and 475). The first wheeled cart probably used solid logs for wheels (Figure 476). This marked an important advance in the development of our modern vehicle. Later the two-wheeled cart came into common use, but not until the seventeenth century did four-wheeled carriages appear in any great number. These were made practical by building better roads.



Courtesy Studebaker Corporation

Fig. 476. An Early Wheeled Cart

This picture, made from an early drawing, does not show us how the logs were attached.

Today our land vehicles are propelled by steam, gas, and electrical power. The first inventor who succeeded in propelling a vehicle by steam was Cugnot, a French army officer, in 1769. His machine (Figure 477) traveled on ordinary roads at the rate of three or four miles an hour, and had to stop every ten minutes to get up steam. This does not appear to have been very much of a success, but it is important because it proved that vehicles could be propelled by steam. Then followed years of experimentation (Figure 478), and finally the first successful locomotive to run on rails was invented by George Stephenson, an Englishman, in 1829. The first practical railroad in the United States was built in 1831, and in 1869 the first

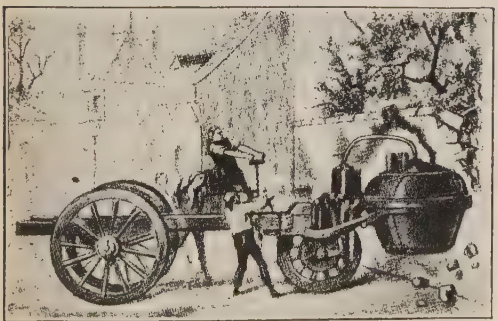
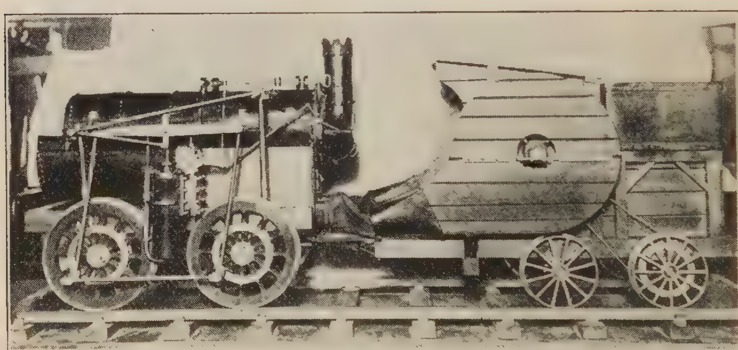


Fig. 477. Cugnot's Steam Engine

It must have been difficult to steer, for this old drawing shows it in the act of colliding with a stone wall. At one time it turned over while making a sharp corner at three miles an hour.

transcontinental railroad was constructed. Since that time the steam locomotive has been greatly improved, electric locomotives have come into use, and new inventions, such as the air-brake and the automatic signal, have greatly increased the safety of railroad travel.

The rise of the gasoline automobile to its present importance has been one of the greatest achievements of our modern age.



Underwood and Underwood

Fig. 478. An Early Attempt at Steam Locomotion

This model of a locomotive was built by Seguin, a French engineer, in 1826, two years before Stephenson built the first "modern" locomotive.

The first successful application of the power of the gas engine for driving a vehicle was in 1887. The table below shows the tremendous growth which has taken place in the United States.

TABLE XVI: GROWTH OF THE AUTOMOBILE INDUSTRY

YEAR	AUTOMOBILES MANUFACTURED
1890-93	2 or 3
1899	3,700
1904	21,975
1909	127,731
1914	569,045
1917	1,868,947
1922	2,659,064
1923	4,014,000
1924	3,637,078

One of the far-reaching results of the invention of the automobile has been the improvement of roads. Thousands of miles of hard-surfaced highways are completed each year, and it is possible to go hundreds of miles without being forced to travel on dirt. In some parts of the country the automobile is

Courtesy Chicago, Milwaukee and St. Paul R. R.

Fig. 479. An Electric Locomotive

This is the latest and most powerful type of electric locomotive. It is used for transportation through the mountainous regions.

successfully competing with the steam railroad both in carrying passengers and in hauling freight. Its extensive use on the farm and in the city has solved many of our transportation problems.

Electric cars have also proved very practical for street railways and for short lines between cities. Recently electric trains have been operated successfully in mountainous regions where water power is plentiful for generating electricity (Figure 479). At the present time the production of electricity is so expensive that it cannot successfully compete with steam when long distances must be traversed. In the years to come the water power of our country will be more fully utilized to produce

cheaper electrical power, and this method of transportation will be more fully developed.

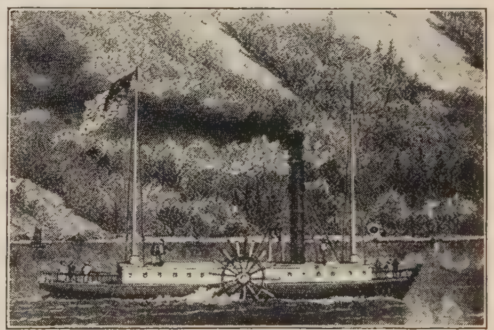
Transportation by water has also undergone many changes since man first learned this method of travel. It is not known when he first discovered that rivers and other bodies of water could be crossed by means of rafts or hollowed-out tree trunks. Probably man's first attempt at navigation was astride a tree trunk, which supported his weight but did not allow him to carry his belongings with him (Figure 480). Not satisfied with this, he must have thought of binding several trunks together so that he could carry a load. It was probably later than this that the hollowed-out tree trunk, or "dug-out," came into use. The dug-out enabled man to travel faster than he could on the clumsy raft, but it cut down the size of his load. Since these first discoveries, man has constantly tried to produce boats which could carry heavy loads, and at the same time, could be easily propelled through the water. The attempt to combine the useful characteristics of the raft and those of the dug-out has resulted in the many kinds of boats which we have today.

Fig. 480. A Log Boat

This was probably man's first method of crossing large bodies of water.

Not only has man learned to build larger and larger ships and to construct them out of strong materials, such as iron and steel, but he has also greatly improved his method of driving them through the water. For several thousand years man contented himself with propelling his boat by hand. The galleys used in the time of the Romans were driven through the water mainly by huge oars manned by slaves. The earliest example

we have of a sea-going boat using sails, is an old Egyptian scene carved on the walls of a temple about 2800 B. C. Long before that time man had probably discovered that the force of the wind could be used to drive small boats. But he was first obliged to discover how the sails could be attached to the boat, how to shift his sails to meet the winds from different directions, and then to construct his boat so that the force of the wind would not upset it. Man power and wind power furnished the only means of propelling boats until the latter part of the eighteenth century.



Keystone View Co.

Fig. 481. The Clermont

The Clermont made the trip between New York and Albany, a distance of 150 miles, in 32 hours, an average rate of about 5 miles an hour.

Many attempts to build a boat propelled by steam were made, but the honor of constructing the first practical steamboat goes to Robert Fulton, who ran the steamship *Clermont* up the Hudson River on August 17, 1807 (Figure 481). The early steamships were propelled by paddle wheels of a type generally used on inland waters today. The first boat to use the *screw propeller* was the *Robert F. Stockton*, in 1839. Since that time the screw propeller has entirely replaced the paddle wheel on ocean-going boats and on many lake boats. On small boats, the fuel oil engine and the electric motor have taken the place of the heavier steam engine, especially in lake and river transportation.

The great changes which have taken place in water transportation can be summarized by comparing the flag-ship of Columbus with a modern ocean liner. The *Santa Maria* was

63 feet long and 20 feet wide (Figure 482). It depended entirely on wind power and could carry only about 150 tons. A crew of 52 men was required to man it. Columbus made his first trip across the Atlantic in about two months. One of our modern great ocean liners (Figure 483) is 920 feet long and 100 feet wide. It can carry a load of 30,000 tons. A crew of over a thousand is required to care for the passengers and to run it, and in addition it carries over 4500 passengers. Only five days are required to cross the Atlantic between Southampton and New York City. In carrying capacity one ocean liner of this size is equal to 200 ships like the *Santa Maria.* In addition to this, it can make ten transatlantic trips in the same time that it took the *Santa Maria* to cross the ocean once.

Courtesy Rau Studio

Fig. 482. The Santa Maria

It required a great deal of courage to brave the stormy seas in a small boat like this, and yet some of the greatest sea voyages in history were made in ships of about this size. Compare this picture with Figure 483.

As far back as the Middle Ages men began to wonder if there was not some material which could float in the air like a ship upon the water. It was not, however, until 1783 that the first balloon was invented. The Montgolfier brothers, who lived in France, had observed the clouds which floated in the air, and they conceived the idea of filling a bag with a cloud of smoke (Figure 484). This they did, and to their great satisfaction, the bag ascended. Their next step was to fasten a basket to the bag and send up live animals. Finally Pilatrude Rozier volunteered to go up in it. On his first ascent the

balloon was held captive by ropes, but on November 21, 1783, Rozier and his friend the Marquis d'Arlandes ascended in a free balloon and remained in the air for twenty-five minutes. The heated air used by the Montgolfiers was soon replaced by hydrogen, which is very much lighter than hot air and possesses

Keystone View Co.

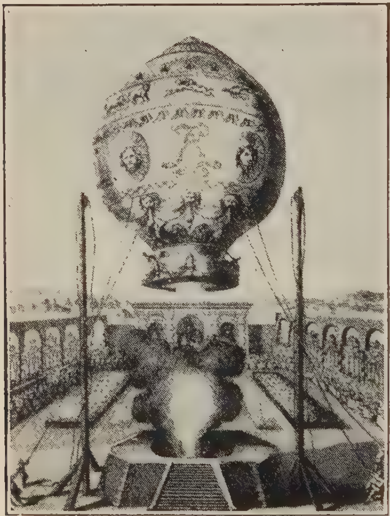
Fig. 483. The Leviathan

This great ocean liner does not have room enough to turn in a harbor. These tug-boats are pushing it around. It has made the trip across the Atlantic in 5 days, 6 hours, and 20 minutes.

a greater lifting power. Since the early days of balloon construction, much progress has been made, and now we have the huge, *dirigible* balloons. These can be steered, can carry tons of materials, and can remain in the air for many hours.

While these successful experiments were being made with the balloon, man was still trying to develop a flying machine which was heavier than air and which could be driven at a high speed.

Probably the first airplane which left the ground carrying a man was made by Ader, a Frenchman, in 1890. The balance of his machine was poor, however, and the machine was not practical. To be practical, an airplane must rise from the ground under its own power, fly through the air under perfect control, and return safely to the ground. The honor of inventing the first practical airplane goes to Orville and Wilbur Wright, of Dayton, Ohio, who in 1903 made many successful flights (Figure 485). The last few years have seen the development of planes which can fly through the air at a speed of three miles a minute and make trips of hundreds of miles without landing.



From Compton's Pictured Encyclopedia
Used by Permission

Fig. 484. The Montgolfiers' Balloon

As you see, hot air and smoke were used to fill the balloon. At the second ascension a rooster, a duck, and a lamb were sent up in a basket. To the astonishment of all, they came down uninjured.

Each of the methods of transportation has its own problems. One of the greatest of land transportation problems is that of securing *traction*. A force is used to drive the wheels and propel the vehicle forward. In order to do this there must be sufficient friction between the wheels and the ground to keep the wheels from slipping. In water transportation the problem of propelling the boat forward is more complicated, since water does not present a solid surface like land. In addition to this is the problem of keeping afloat vessels constructed of iron and steel, since these materials are heavier than water. The problems in air transportation depend on whether a heavier-than-air or a

lighter-than-air ship is to be used. In balloons and dirigibles a lighter-than-air gas must be secured. In the airplane the resistance of the air must be utilized to enable the propeller to keep the plane up in the air and to steer it in its course.

PROBLEM 1: WHAT ARE SOME IMPORTANT SCIENCE PROBLEMS CONNECTED WITH LAND TRANSPORTATION?

Power must be applied to the driving wheels. Transportation, to be effective, must be speedy. In utilizing the force of expanding steam, exploding gas, and electricity, many difficulties had to be overcome. You recall (see page 377) that the motion of the piston in the steam or gas engine is backward and forward or upward and downward. Such motion has to be changed to *curvilinear* motion; that is, the circular movement of the wheel. This is accomplished by the use of the eccentric in the steam engine (Figure 359) and by the crank shaft of the automobile (Figure 373).

Keystone View Co.

Fig. 485. The Wrights' First Airplane Flight

This picture shows one of the Wright brothers standing at the right and the other lying on the middle of the lower wing, operating the plane. The plane stayed up 59 seconds and flew 260 yards. Two years later the brothers made a flight of 24 miles.

The power must then be transferred to the driving wheels. The method of doing this depends upon the kind of power used. In the steam engine the force of the expanding steam can be applied directly to the drive wheels. This is possible because the power of the engine does not depend upon the speed at which the engine is moving. As soon as the steam enters the cylinder, it develops its full power. This is not true in the case of the gas engine or electric motor. The greater the speed of the gas engine or electric motor, the greater is the power developed.

Since it requires a much greater force to set an object in motion than it does to keep it moving, it is clear that the engine itself must be running at high speed before the car can be started. Of course it would be impossible to attach the engine to the driving wheels when it is going at a high speed and the wheels are not moving. For this reason automobiles are equipped with a clutch (Figure 373), which disconnects the engine from the system of gears which transmit the power to the rear wheels. (See page 386.) A system of gears is also necessary in an electric automobile, although it is not necessary to shift them as it is in the gasoline automobile.

Courtesy Portland Cement Association

Fig. 486. A Muddy Country Road

On a road like this, several teams of horses are required to pull a heavy load.

Exercise 1. Why does a gas engine transmit more power to the drive wheels when it is running rapidly than when it is running slowly?

Traction for the wheels is secured by friction. Another difficulty which is encountered in land transportation is that of securing traction. The surface over which the wheels run must be neither too rough nor too smooth, in order to provide sufficient friction between the wheels and the surface upon which they turn. The early steam carriages failed largely because they could not secure proper traction on the roads. The development of railroads was delayed one hundred years because some mathematicians figured out that there would not be enough friction between iron wheels and iron rails to provide traction for a locomotive.

If you have ever taken an automobile trip on muddy roads, you realize the need of good traction (Figure 486). The car

slips from one side of the road to the other, and much greater power must be used to attain the speed that could be secured on dry roads. Wrapping chains around the tires is simply a method of securing the foothold necessary to propel the car forward. Non-skid tires with their irregular outer surface are used for the same purpose. In the country the farmer uses cleats on his wheels or wraps them with rope. Hard-surfaced roads are overcoming this difficulty, and are making for safety and comfort in overland travel (Figure 487). The roads which are now being built are also so well graded that the wheels are constantly in contact with the roadbed, so that good traction is secured. This makes possible the use of low-power cars.

Courtesy Portland Cement Association

Fig. 487. A Concrete Highway

This is a picture of the same road shown in Figure 486.

Exercise 2. Why is it dangerous to drive fast on a wet pavement?

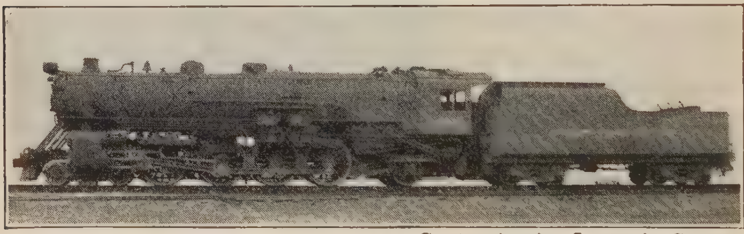
Exercise 3. Why do tractors and traction engines have cleats on the wheels?

Exercise 4. Locomotives and electric street cars are equipped with a device to pour sand in front of the driving wheels. When does an engineer or motorman use this device? Explain.

Friction must be reduced in the moving parts of a machine. You recall (see page 326) that the efficiency of a machine depends upon the amount of friction. Friction not only lowers the efficiency of a machine, but it causes the parts to wear out. For this reason automobiles are equipped with ball-bearings and with a lubricating system which covers movable parts with a film of oil and prevents the metal surfaces from coming into contact with each other. The gears (Figure 373) run in

a bath of heavy oil, and the wheels, springs, axles, and steering device are packed with hard grease. An abundant supply of oil is especially important in the engine, for without it the engine will become over-heated, causing the pistons to expand, the valves to warp, and the entire engine to be damaged.

Shocks and jars must be eliminated. Comfort in riding is another important factor which must be considered in all forms of land transportation. Both the automobile and the train are equipped with springs which absorb the shock from irregulari-



Courtesy American Locomotive Company

Fig. 488. A Powerful Locomotive

Observe the short smoke stack and the rounded sides of the locomotive and tender. By this construction the resistance offered by the air is lessened.

ties in the surface over which the wheels are run. This not only softens the shock to the rider, but at the same time reduces the wear on the car. Automobiles are equipped with air-filled tires. When the tire strikes a bump, the air in the tire takes up part of the shock. Balloon tires, which are much larger and which carry air at a very much lower pressure than ordinary tires, are proving satisfactory in further decreasing the wear and tear on the rider and the car.

The surface offered to the resistance of the air must be as small as possible. Air offers so little resistance when one is walking that it is hard to realize that air resistance must be taken into consideration in designing locomotives and automobiles. This is necessary, however, if high speed is desired, because if the speed is doubled, the resistance of the air becomes

four times as great, and if it is tripled, the air resistance becomes nine times as great. For this reason we have the *stream-line* automobile and locomotive (Figure 488). When they are constructed in this manner, the air which strikes them flows off at the sides.

New methods of transportation will be developed. When one realizes that all of the important advances in transportation were made during the last one hundred years, it is easy to believe that the next century may unlock new forces which will be used to propel our vehicles, and new machines may be invented which will change methods of transportation as greatly as the inventions of the past century have done.

Exercise 5. Racing cars do not use wind-shields. Why?

Exercise 6. What causes squeaks in an automobile? How can they be eliminated?

Exercise 7. Some automobiles are equipped with "shock absorbers." Of what value are these to the car and to the passengers?

PROBLEM 2: WHY DO BOATS AND SHIPS FLOAT?

Primitive man probably did not spend much time wondering why his boat floated; he was satisfied that it did. It is easy for you to see why wooden ships float, because you know that if you throw a piece of wood on the water it will not sink. It is perhaps not so easy to understand why boats made of iron, steel, or concrete, float, because these materials will sink when placed in water. If you roll a piece of tinfoil into a ball and place it in water, it will sink. If you then unroll the tinfoil and bend it up on the sides so as to make a little boat, it will float. If you can explain why it sinks when rolled into a ball and why it floats when smoothed out and made into a boat, you will be able to explain why iron and steel ships float.

Materials weigh less in water than in air. Perhaps you have noticed that you can lift yourself with your hands very easily while in the water. You seem to weigh much less in the water than out of it. This will help you to understand how iron ships float.

Experiment 104: Do materials weigh less in water than in air?

(*a*) Suspend a stone or piece of iron from a spring balance, and record the weight.

(*b*) Lower the stone or piece of iron in a jar of water until it is completely covered, and again note the weight (Figure 489). Does it weigh the same as it did in air?

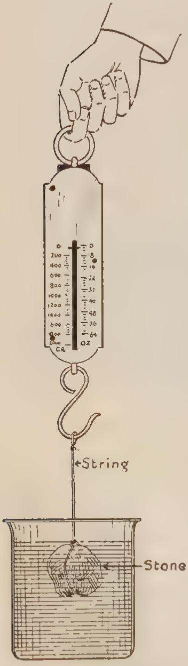


Fig. 489. Apparatus for Experiment 104.

From your experiment you see that materials weigh less in water than in the air. The water must overcome part of the force of gravity, because the amount of material is the same. This lifting force of water on a body placed in it is called *buoyancy*.

Two forces act upon objects placed in water. When an object is placed on water, there are two forces acting upon it. There is the pull of gravity which tends to make it sink, and there is the lifting effect of the water which tends to make it float. If the pull of gravity is greater than the lifting effect of the water, the body sinks. If the upward force of the water is greater than the weight of the body in air, it then floats.

Experiment 105: Why does wood float?

(*a*) Obtain a block of wood 10x10x10 centimeters, and weigh it in grams. Calculate the weight of wood per cubic centimeter.

(*b*) Completely fill with water a jar or beaker somewhat larger than the block of wood, and place the beaker in a pan.

(*c*) Place the block of wood in the water (Figure 490). Observe that it sinks a little and pushes aside, or *displaces*, some of the water, which overflows into the pan.

(*d*) Measure the number of cubic centimeters of water which were displaced. A cubic centimeter of water weighs one gram; so the weight of the water displaced will be the same number of grams as cubic centimeters. Compare the weight of the water displaced with

that of the block of wood. (Keep in mind that a little of the water displaced sticks to the walls of the vessel.)

Experiment 105 shown you two facts: (1) the wood sinks in the water until it displaces an amount of water equal to its own weight, which means that the bouyant force of the water is equal to the weight of the water displaced; (2) a cubic centimeter of wood weighs less than a cubic centimeter of water. Since the wood does not weigh so much as an equal volume of water, it sinks only part way, until it displaces its own weight. Part of the wood, therefore, remains out of the water.

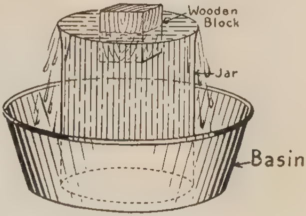


Fig. 490. Apparatus for Experiment 105

If you repeat Experiment 105, using a piece of iron or a stone, you get somewhat different results.

Experiment 106: Why do iron and stone sink when placed in water?

Repeat the last experiment, using a piece of iron or stone. In this experiment you find that the weight of the water displaced is less than the weight of the iron or stone. Since the upward or buoyant force is equal to the weight of the water displaced, the iron or stone sinks, because the lifting force is not equal to the weight of the iron or stone. Floating objects always sink in water until they have displaced their own weight. Objects heavier than water always sink, because their weight is greater than the weight of water they can displace.

Steel ships float because the *average weight* of each cubic centimeter or cubic foot of the ship is less than the weight of a cubic centimeter or cubic foot of water. This is true because there are great air spaces between the steel walls of the ship, and the ship is constructed so that it will displace a large amount of water.

Exercise 8. A lake boat weighs 25,000 tons and carries a load of 10,000 tons. How many cubic feet of water will it displace? (A cubic foot of fresh water weighs 62.4 pounds.)

Exercise 9. How can an engineer plan a boat so that before it is built he will be able to tell how far down in the water it will sink and how much of a load it will carry?

PROBLEM 3: HOW ARE SHIPS PROPELLED AND STEERED?

Sail boats use wind power to propel them. Boats propelled by wind are still used in many places, although the steamship, because of its greater speed and carrying power, is gradually displacing them for ocean travel. Skaters often use the force of the wind to blow them over the ice. Coming against the wind, they have to use their own energy, because they do not know how to make the wind drive them back against it. Sailors found long ago that they could not wait for the wind to blow in the direction they wished to go. They learned how to harness the wind and make it drive them where they willed. Sailing against the wind is simply a matter of adjusting the position of the sail and rudder so that the angle at which the wind strikes the sail is changed. Figure 491 shows how the sails of a boat should be arranged in order to sail into the wind.

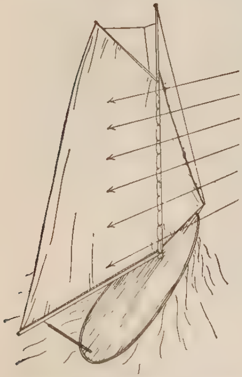


Fig. 491. Sailing a Boat into the Wind

The air spills over the side of the sail, and a forward push is given to the boat.

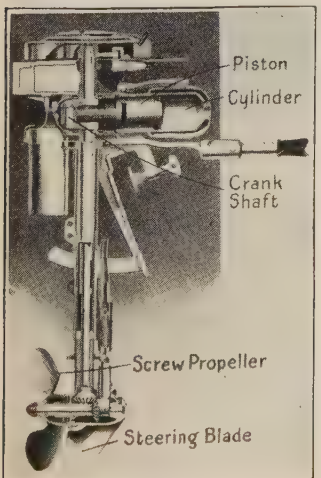
It is of course impossible to sail in exactly the same direction from which the wind blows. For example, if the wind were due north, and one wished to travel due north, it would be necessary to "tack," that is, to sail northeast or northwest. By first sailing slightly northeast and then changing the sail so as to travel northwest, it is possible to maintain an average northerly direction.

Steam boats are propelled by the paddle wheel and screw. Two methods of propelling steamships are in common use. The older method is that of the large revolving wheel fitted with broad blades or paddles. The wheels may be placed one on each side of the boat, or only one may be used at the stern (Figure 492). Since water has weight, it offers resistance to the passing of the blades through it. Therefore, as the wheel turns and the blades strike the water, the boat is pushed forward. The more modern propeller is shaped like the curved blades of an electric fan (Figures 493 and 494). It revolves rapidly through the water, pushing the boat forward.

Keystone View Co.

Fig. 492. A "Stern-Wheeler"

This type of boat is used in shallow water where a screw propeller will not work.



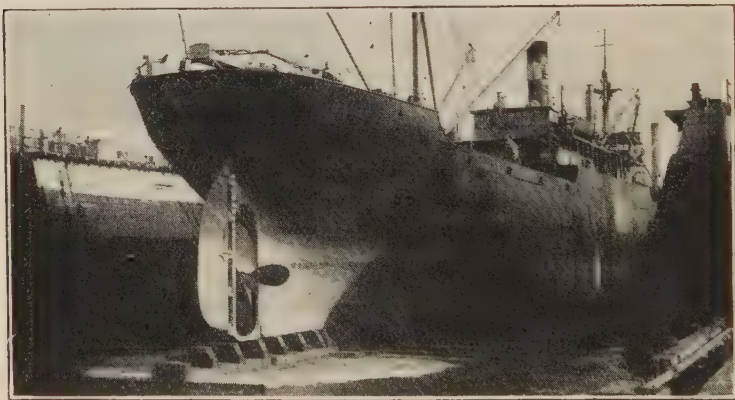
Courtesy Evinrude Co.

Fig. 493. A Portable Gasoline Engine

Ships may be driven by one, two, or three screws. If the ship is driven by one screw, the shaft from the engine which drives the screw issues from a hole in the stern frame in front of the rudder. If two screws are used, one is placed on each side of the stern frame. If three screws are used, one is in the stern frame, and one is placed on each side of the stern

frame. A three-screw ship has several advantages over a one-screw ship. In the first place, in case one screw is disabled, or if the engine which drives it breaks down, the ship can still be propelled by the other screws. It is also possible to drive the screws at different speeds, so that the ship can be steered without a rudder. This is of special value when the ship is being turned around.

Exercise 10. State the advantages and disadvantages of the different methods of propelling ships.



Ewing Galloway

Fig. 494. A Ship in Dry Dock

The screw propeller and rudder are clearly visible at the stern of the boat. The dock shown here is a floating dry dock. It is really a big open tank with water-tight spaces between the walls, which may be filled with or emptied of water to raise or lower the dock, as may be desired.

The compass is an aid to steering. When you travel on land, it is comparatively easy to find your way. Roads are laid out in more or less regular lines, and it is hardly necessary even to know the directions. On the ocean, travel is a different matter. When land is out of sight, the only natural direction-finders are the sun by day and the stars by night. Navigators need to know, however, their exact position, so that they may be sure of traveling toward their destination in a reason-

ably direct route, and so that they may avoid shallow water and rocks.

No one knows exactly when or where the *compass* (Figure 495) originated, but history tells us that it was in use during the twelfth century. The compass dial, or card, was divided into thirty-two parts and permanently marked before the close of the fourteenth century. The four *cardinal points*, north, east, south, and west were, of course, a part of man's knowledge thousands of years ago.

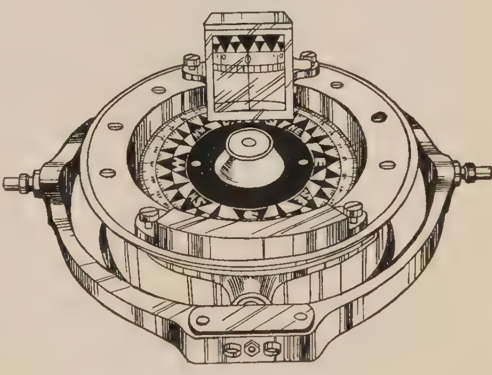


Fig. 495. A Mariner's Compass

Underneath the compass card is a revolving framework to which both the compass needle and the compass card are attached. Therefore, as the needle is pulled around, the card moves with it. In the mirror at the back, the helmsman can read the number of degrees that the card has revolved to the east or west.

If a piece of steel is magnetized and mounted in such a way that it may move freely, one end of it will point in a northerly direction. This end is called the *north-seeking* pole of the compass *needle.* Without doubt the ancients believed that the compass pointed to true north, but in most places on the earth's surface it really points several degrees to the right or left of true north. Experiments also showed that as the compass was carried north or south on the surface of the earth, the needle tilted up or down. This led scientists to believe that the earth possesses *magnetic poles.* Sir James Ross in 1831 located the north magnetic pole of the earth. At that point the north-seeking end of the compass needle points straight down. This location was found to be about 1200 miles from the geographical north pole. Because

of the difference in the position of the two poles, the compass needle will not point true north. Since 1831 maps have been constructed to show the difference between true north and the magnetic north (Figure 496). This difference is called the *magnetic declination.*

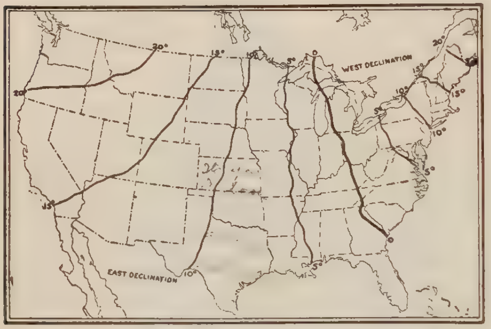


Fig. 496. Magnetic Declination in the United States

If a place is east of the line marked 0°, the compass needle will point west of true north.

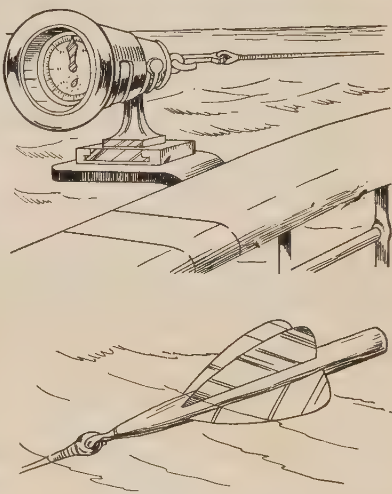
Exercise 11. Locate your town or city on the map shown in Figure 496. What is the magnetic declination? Is it east or west declination?

The compass is very useful to steer by, but it does not tell you how far you have traveled or where you are located at any particular time, and so other instruments have been invented to give this information.

The "log" records the rate of travel. Columbus had no idea of the distance he traveled, because he had no way of measuring it. The first device for measuring distance traveled appeared early in the seventeenth century. This instrument was called the *log.* It consisted of a stick of wood attached to a rope. On the rope were knots placed at regular intervals of about 50 feet. When navigators wished to find out how fast the ship was going, they threw the log overboard, and a sailor counted the number of knots which slipped through his hand in a given time, as measured by a half-minute sand glass. The number of knots which passed through the sailor's hand in the half minute represented the number of nautical miles made an hour by the boat. The nautical mile is 1.14 times as long as the ordinary mile. The word *knot* is generally used by sailors to mean the nautical mile. The actual distance traveled a day

can be determined by obtaining the average speed an hour and multiplying it by 24. The log used now consists of a steel torpedo-shaped rotator attached by a cable to a speedometer on the ship's rail (Figure 497). The speed at which the rotator turns depends upon the speed of the ship. The small hand on the recording instrument indicates the rate of travel. The log, when used with the compass, furnishes a very rough estimate of the ship's position, but this method is always checked by means of other instruments.

Exercise 12. How many knots would pass through the sailor's hand in half a minute if the boat was sailing ten nautical miles an hour?



Courtesy Compton's Pictured Encyclopedia

Fig. 497. A Mariner's Log

In the upper part of the picture is shown the speedometer attached to the ship's rail. The cable leads out to the rotator, shown below. As this rotator is dragged through the water, it revolves, turning the gears in the speedometer.

Latitude and longitude can be determined. In order to obtain the exact position of a ship it is necessary to determine its latitude and longitude. The latitude fixes the distance north or south of the equator, and the longitude fixes the distance east or west of the prime meridian at Greenwich. (See page 30.) This distance is measured in terms of degrees (°), minutes (′), and seconds (″). By means of a map the navigator may easily determine the latitude and longitude of different places. In the same manner the master of the ship, having once determined his latitude and longitude, can, by means of the map, locate his exact position.

Longitude is determined by means of a *chronometer* and a *sextant*. The chronometer is simply a very accurate clock. Usually ships carry two chronometers; one is set according to Greenwich time (see page 31), and the other shows ship time, that is, actual time of day on board the ship. The sextant is an instrument used to measure the angle of the sun or some other heavenly body with the horizon line (Figure 498). Just

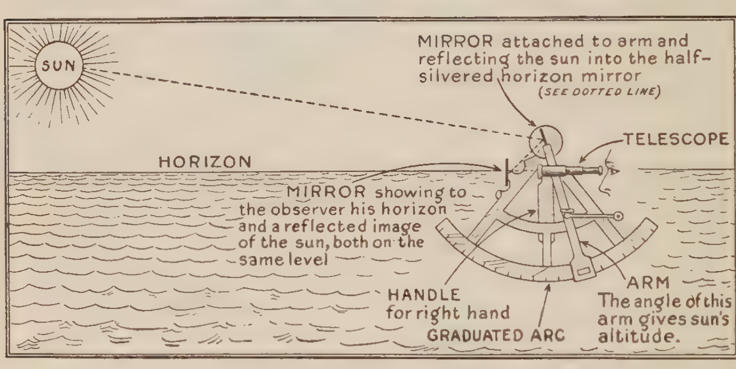


Fig. 498. How a Sextant is Used.

before noon, according to ship time, one of the ship's officers begins his observation of the sun. The handle for the right hand is held in a vertical position, and the horizon line is sighted through the telescope. Then the movable arm is adjusted until the light from the sun is reflected by the upper mirror to the horizon of the horizon mirror. When the sun has reached its highest point, it will be exactly 12 noon. Comparison is then made between ship time and Greenwich time. Suppose that Greenwich time is 11 A. M. and the ship time is 12 noon. The difference in time is one hour. This means that the ship is at 15° East longitude. (See page 31.)

The latitude is determined by means of the sextant. You know that on September 23rd and March 21st the sun is directly over the equator at noon. (See page 27.) It therefore makes an angle of 90° with the horizontal (Figure 499*A*). If

one were located at the north pole on these days, the sun's rays would be horizontal; that is, one would see the sun by sighting directly along the horizon. If one were half way between the equator and the North Pole, that is, 45° latitude, the angle of the sun's rays would make an angle of 45° with the horizontal (Figure 499*B*). Therefore on these two days the latitude may be determined by simply measuring the angle of the sun's rays with the horizontal at 12 noon. Since, however, the sun is not always directly over the equator, it is necessary to correct the angle according to the time of year. Navigators carry charts which give the correction for each day of the year. In determining the latitude, therefore, the angle of the sun with the horizon at 12 noon is determined with the sextant. This is the angle between the vertical arm and the movable arm when the sextant is correctly sighted at noon. This angle is then corrected according to the time of year. When the corrected angle is obtained, it is only necessary to look in the tables to find the correct latitude.

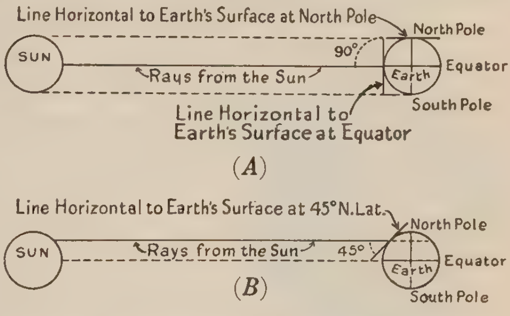


Fig. 499. Determination of Latitude on September 23rd and March 21st

At night, when the sun is not visible, the navigator obtains his position from the stars. The invention of radio and the *radio compass* has made it possible for the ship captain to work out his position by radio or to obtain it from radio stations.

Exercise 13. A ship captain made the following observations of his position on the twenty-first of September: ship time, 12 noon; Greenwich time, 9 A. M.; position of sun at noon, 22°. What were the latitude and longitude of the ship? (See Figure 499.)

PROBLEM 4: HOW DO BALLOONS AND DIRIGIBLES FLOAT IN THE AIR?

The balloon is a great gas bag. The bag of the modern balloon is made of varnished silk or cotton treated with a rubber solution. The varnish and the rubber prevent the gas from leaking through the walls. On the outside of the bag is a strong *net* to which the basket is fastened (Figure 500). The basket is usually made of bamboo or woven willow materials, which are very strong and light. In the side of the balloon near the top is the *ripping panel*. This consists of a light fabric sewed between two of the panels. When the *ripping-panel cord* is jerked, the fabric is torn open, and the gas escapes. This enables the aeronaut to make a quick descent. There is also a valve in the neck of the balloon, which is opened automatically and prevents the balloon from bursting if the pressure inside becomes too great.

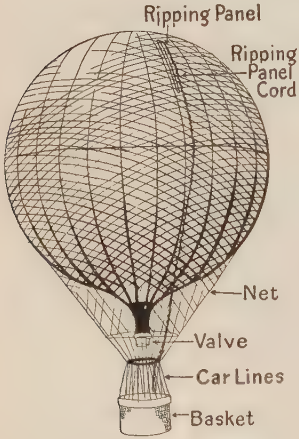


Fig. 500. Parts of a Balloon

Balloons cannot be steered and are therefore at the mercy of the wind.

Balloons are filled with a lighter-than-air gas. To send a balloon up it is necessary to fill it with a gas which weighs much less than air. Hot air, coal gas, hydrogen, and helium have all been used for this purpose, because they are all lighter than air.

Experiment 107: How are balloons inflated?

(*a*) Make some soapy water by dissolving soap in warm water and adding a little glycerine. Attach a soap-bubble pipe to the gas jet by a rubber tube. Dip the bowl of the pipe in the soapy water, mouth downwards, and turn the gas on slowly. When the soap

bubble gets to be about four inches in diameter, shake it off. What does the bubble do?

(*b*) A rubber balloon may also be filled with hydrogen. Generate a gallon bottle of hydrogen. To do this, place about 10 grams of zinc in the bottle and add 20 cubic centimeters of hydrochloric acid. Place the stopper in the bottle, as shown in Figure 501, but do not connect the rubber tube with the faucet. After a few minutes connect the tube which goes to the bottom of the bottle to the faucet, and connect the other tube to the balloon. When the faucet is opened, the water will force the gas out of the bottle into the balloon. As soon as the balloon is completely inflated, pinch the end of it so that the gas cannot escape, and tie it securely. Take it out doors, release it, and see how high it goes.

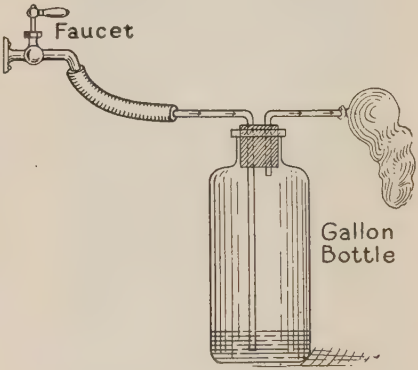


Fig. 501. Filling a Toy Balloon with Hydrogen

One thousand cubic feet of air at a pressure of thirty inches of mercury and a temperature of 60°F. weigh about 75 pounds. One thousand cubic feet of coal gas at the same temperature and pressure weigh but 37½ pounds. The same volume of hydrogen weighs but 5 pounds. The *lifting force* of the gas in the balloon is the difference between the weight of air and the weight of the same volume of gas. For example, the lifting power of hydrogen is 70 pounds per thousand cubic feet. Why? What is the lifting power of 1,000 cubic feet of coal gas? To calculate how heavy a load a balloon can lift, you must know four things: the weight of the balloon, its volume, the weight of the air it displaces, and the weight of the gas used to inflate it. Suppose you wish to find the lifting power of a balloon inflated with coal gas, the volume of which is 100,000

cubic feet, and the weight 1,000 pounds. In order to see how this is done, arrange your data as shown below.

Weight of balloon...1000 pounds	Weight of air displaced (100×75)...7500 pounds
Weight of 100,000 cu. ft. of coal gas (100×37.5)......3750 pounds	Total weight of balloon and gas.....4750 pounds
Total weight of balloon and gas.....4750 pounds	Lifting power of balloon.............2750 pounds

Ballooning requires great skill. Let us now see what the balloonist does when he goes on a trip. First he must inflate the bag. For this purpose he may have the bag suspended in the air, or it may be lying on the ground with the neck underneath. If he uses hydrogen, it is only necessary to let the gas escape from big steel cylinders which contain the hydrogen under great pressure. As the gas rushes in, the bag grows larger and larger. At first the balloon displaces but little air, but as it swells it displaces more air. As a rule the bag is not fully inflated, because as it rises, the air pressure gets less, and the gas in the balloon expands. When the weight of the air displaced is greater than the weight of the balloon, the bag begins to tug at its moorings, and when released shoots up into the air.

As it ascends, the gas inside the balloon expands, because the air pressure outside grows less. The automatic valve in the neck of the balloon opens when the pressure inside gets too great, and part of the gas escapes. The balloon continues to rise until it reaches a level where the air displaced equals the weight of the balloon. If the pilot wishes to go higher, he can throw out *ballast*. This usually consists of bags of sand. Relieved of this weight, the balloon will rise. If the pilot wishes to float at a lower level, he can open the valve and allow part of the gas to escape. Since the volume of the balloon becomes smaller, the balloon must sink to a lower level where the air is heavier.

All of this time the balloonist is at the mercy of the wind. He does not feel the slightest air movement, because his balloon is floating along at the same rate of speed as the wind. If he gets out of sight of land, he has no means of telling how fast he is going or in what direction. As the balloon travels, it generally revolves slowly. Of course the basket turns with it, so that even the compass will not tell the pilot his direction. If it were not for the leakage of gas, a balloon could remain in the air indefinitely. But because of this leakage it must finally come down. When it nears the ground, the *trail rope* is of great assistance in making a good landing. The trail rope is a heavy cable, and when the balloon comes so low that the rope touches the ground, the balloon is relieved of part of its weight and becomes more buoyant. As the balloon comes nearer to the ground, the dragging trail rope also cuts down the speed of the balloon.

Keystone View Co.

Fig. 502. Descending with a Parachute

This parachute is high in the air, as you can see from the fields below it.

One sometimes sees a balloonist jump from the balloon and descend in a *parachute.* The parachute is a large umbrella-like structure (Figure 502) which is opened by the air as the balloonist falls. The resistance of the air buoys it up, and thus causes a gentle descent. Just before the pilot jumps, he pulls the ripping panel, and if the balloon is filled with coal or wood gas, you can see the huge clouds of black smoke pouring out.

A dirigible or airship is more complicated than an ordinary balloon. The dirigible balloon or airship must be long and

pointed, with a stream line, so that it may be driven into the wind (Figure 503). The bag must also be rigidly constructed,

Pacific and Atlantic Photos

Fig. 503. Dirigible Airships

The Los Angeles is 656 feet long and holds 2,500,000 cubic feet of helium gas. At the time this picture was made, the other dirigibles were in the process of construction. The length of the G-Z-1 type is 900 feet.

or nearly so. In one type of airship the bag is attached on the outside of a framework of aluminum which makes the bag rigid. Another type contains air bags, which, as the gas escapes, may be pumped full of air. The dirigible is propelled by gasoline engines which drive propellers, and is steered by a huge rudder at its rear. The first airship crossed the Atlantic in July, 1919. This ship was six hundred and forty feet long and had five engines, which altogether developed one thousand horse power. The *Los Angeles*, one of the later dirigibles, is 656 feet long and will carry more than forty tons of useful load. It has a cruising radius of about five thousand miles. The *Shenandoah*, built in America, has an effective lift of thirty tons and a cruising radius of four thousand miles.

Helium gas is best for balloons and dirigibles. The chief danger of dirigibles and balloons is that of fire. Until a recent date the bags were always inflated with inflammable materials. In the search for a gas which was lighter than air and which would not burn, it was found that helium gas, which has a lifting power 92 per cent as great as hydrogen, could be used. This gas, however, was too expensive to obtain until in 1919, when a process was perfected in our country for securing it from natural gas. It is probable that with the wider possibilities which this gas presents, flying with dirigibles will finally be made as safe as travel on land and sea.

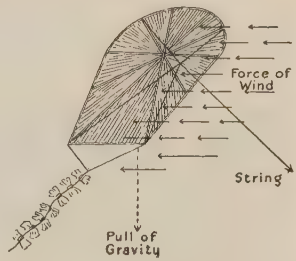


Fig. 504. How a Kite is Held up

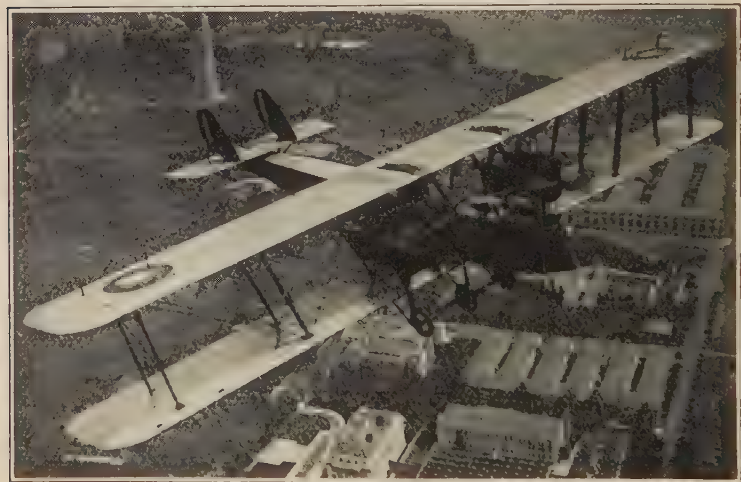
Exercise 14. A balloon weighs 1000 pounds. It is filled with hydrogen and has a lifting power of 1500 pounds. What is the size of the balloon?

Exercise 15. Contrast the operation of a balloon and a boat.

PROBLEM 5: HOW DO AIRPLANES MOVE THROUGH THE AIR?

The airplane resembles the kite and the bird. Perhaps the simplest way to understand how an airplane flies is to see first what keeps a kite in the air. Figure 504 shows the forces which act upon a kite in the air. The wind strikes the under surface of the kite at an angle and produces two effects. One effect is to drive the kite upwards, and the other effect is to push it horizontally. The string keeps the surface of the kite facing the wind at the same angle. If the string were released, the kite would immediately come to the ground, because the force of the wind would straighten the kite out horizontally and there would be no upward push. Acting against the pull of gravity which tends to pull the kite down, is the upward force of the wind. The stronger the wind the greater this upward force

will be, and the higher the kite will go. When you run very rapidly against the wind, the kite keeps mounting in the air, because you are increasing the force of the wind against its surface. If you stop running, the kite will not go higher unless there is a very strong wind. If that part of the force of the wind which produces the upward lift becomes less than the force of gravity, the kite will fall to the ground.



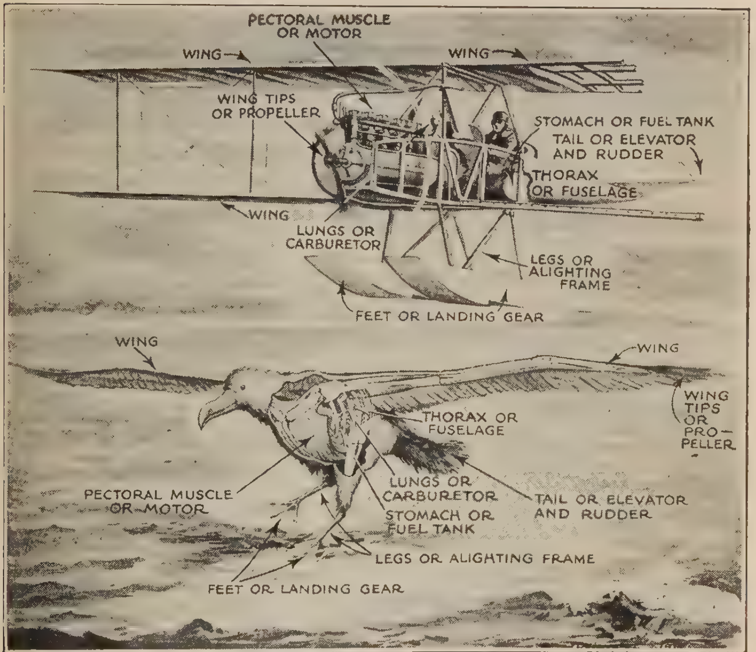
Underwood and Underwood

Fig. 505. A Modern Type of Airplane

Can you name the various parts of the plane, as shown in this picture?

The airplane has been closely modeled after the bird (Figures 505 and 506). The weight of its body is centered near the front, which counterbalances any tendency to whirl over backwards. Its wings are arched, with concave side downward, and are thicker in the front than in the back. The body tapers toward the ends. This cuts down the air resistance exactly as the body and head of a bird do. Its tail balances the effect of the wind on the planes so as to keep an even keel, and furnishes the means of steering.

The propeller blades bore through the air like a screw. Airplanes are always driven with powerful engines, because to remain in the air it is necessary to keep a speed of sixty miles an hour or more. The engine is cranked by turning the propeller,



Courtesy Popular Science Monthly

Fig. 506. Comparison of a Water Bird and a Hydroplane

For hundreds of years man has been trying to produce a machine which will fly through the air like a bird. Perhaps in the future he will accomplish this.

just as an automobile is started with a crank. The propeller cuts through the air at the rate of fifteen hundred or more revolutions a minute. Its action is like that of a screw. If you start a screw into a block of wood and turn it with a screw driver, its curved edges will cut through the wood, pulling the

screw deeper and deeper into the wood. The blades of the propeller are curved in somewhat the same manner, and as they revolve they cut deeper and deeper into the air, pulling the airplane with them. Of course the air is not solid like wood and does not offer as much resistance. Its resistance is enough, however, so that the propeller works its way through it with every revolution. When the propeller is placed in front, it is called a *tractor*, and when placed behind, a *pusher*.

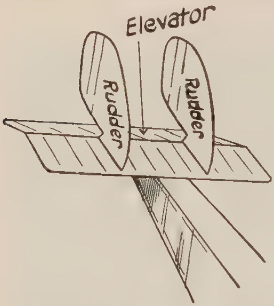


Fig. 507. Airplane Elevator Lowered

The backward-rushing air strikes the under face of the elevator. This exerts an upward pressure on the rear of the plane, which forces the front of the plane downward.

When an airplane is flying through the air at a hundred miles an hour, the force of the wind against it is the same as if it were stationary and a hundred-mile gale were blowing. A wind of this speed is sufficient to blow over trees and wreck buildings. This tremendous force of the wind is directed against the front planes, the body, and the tail. As you recall, the body of the plane tapers toward both the front and rear, so that wind resistance on the body is greatly reduced. Furthermore, the wings, or planes, are not set at such an angle that they will get the full force of the wind. In fact, they are almost parallel with the plane. All these factors make it possible for the plane to exist in the face of the terrific wind resistance which it encounters when moving at such high speed.

The elevator governs the upward and downward course of the airplane. The front planes themselves are not placed at a great enough angle for the machine to "take off" when it is on the ground. When the aviator wishes to ascend, the engine is started, and the propeller drives the machine along the ground. When the pilot is sure that the plane has gained sufficient speed, he pulls the proper lever, which lowers the *elevator*. The

elevator is a small, movable plane or rudder located on the tail. When it is lowered (Figure 507), the pressure of the wind pushes the tail of the plane off the ground. If the elevator is now raised, the pressure of the wind pushes the tail down and the head up (Figure 508). This allows the wind to strike the underside of the planes. The force of the wind lifts the airplane as it does the kite. In descending, the elevator is lowered and the wind pressure lifts the tail and lowers the front planes, thus decreasing the angle at which the wind strikes the front planes. Moving up and down or flying at a level is thus accomplished by the raising or lowering of the elevator.

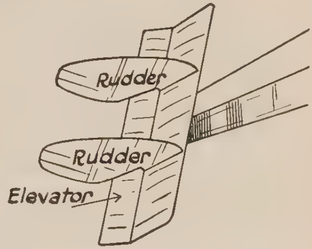


Fig. 508. Airplane Elevator Raised

As the plane speeds forward, the rush of air strikes the raised elevator and exerts a downward pressure on this end of the plane, forcing the front upward.

The airplane is steered largely by means of the *vertical rudder* or *rudders*. These offer resistance to the air current, just as the elevators do. By moving them to the right or left, the pilot can change the direction of the plane.

Exercise 16. Outline the things an aviator must do to "take off," ascend to an altitude of 1000 feet, fly at this level for a mile, and then return to his starting place.

Review Exercise on Unit XVII. (*a*) Turn back to the Preliminary Exercises and mark those which you answered incorrectly or failed to answer. Answer them at the end of your original answers.

(*b*) Turn to the Table of Contents of Unit XVII and see if you can give satisfactory answers to each of the problems in this unit. If you cannot do so, study the text until you can.

Review Exercise on Entire Book. Read "The Story of this Book" in the section entitled "To the Student," and see how much more it means to you now than it did at the beginning of the course.

ADDITIONAL EXERCISES AND PROJECTS ON UNIT XVII

1. State the advantages and disadvantages of transportation by land, by water, by air.

2. Why is it easier to float in water if you take a deep breath?

3. Is it easier to swim in fresh water or salt water? Explain.

4. A flat-bottomed barge is twenty-five feet wide and one hundred feet long. How many thousand pounds of stone must be loaded to make it sink one foot more?

5. If you can just float in water, what is the volume of your body? (Of course you know your own weight.)

6. If you are on the east side of a lake in a sail boat and the wind comes from the west, how can you cross to the west side?

7. A balloon has a capacity of 250,000 cubic feet, and is filled with hydrogen gas. The weight of the balloon and basket is 3000 pounds. How heavy a load will the balloon carry?

8. If you have ever ridden in an airplane, write a report of your experience.

9. Why does a heavy car ride more comfortably over a rough road than a light car?

10. Why is it easier to steer an automobile on a muddy road when one is climbing a hill than when one is going down a hill?

11. Make a survey of the transportation facilities of your town or community.

REFERENCES AND GUIDE FOR ADDITIONAL STUDY

Note to Students: The REFERENCES and GUIDES TO REFERENCES which follow will help you in two ways. First, they may be used for further study of any topic which you do not fully understand during your work on the various units of the course. Second, they will furnish you with many interesting topics and projects for investigation and will give you the page references to a great number of books written by scientists.

The GENERAL REFERENCES (page 516) are books or encyclopedias which will likely be in the school and public libraries. These are general in nature and cover such a wide range of subjects that you will probably be able to find in them brief references to any topic or problem you may wish to investigate. No page references are given for the GENERAL REFERENCES. Use the index for each.

Following the GENERAL REFERENCES you will find for each unit of the course:

(1) REFERENCES—a list of books and pamphlets, numbered in order.

(2) GUIDE TO REFERENCES—page references to the books and pamphlets listed under (1). The numbers in black type correspond to the numbers preceding the books and pamphlets listed under REFERENCES; the numbers following the black type give the page references to the books and pamphlets. (In case the entire book or pamphlet is devoted to the topic, the word "entire" follows the number of the book). Under the heading (*A*) GENERAL are references to books and pamphlets which cover much the same subject-matter as that studied in the unit. Under (*B*) SPECIFIC TOPICS you will find references to particular topics studied in each unit.

(3) Topics and Projects for Investigation—a list of topics and projects which you may wish to investigate. These topics and projects are for students who complete the study of each unit ahead of their class or who, because of special interests or abilities, are given the privilege of doing extra work outside of class. The numbers following each topic refer to books or pamphlets in the list of References. Consult with your teacher before undertaking one of the Topics or Projects.

On page 570 you will find a list of books which you may use to investigate the life and work of Discoverers and Inventors in Science. This list of books is followed by an alphabetical list of persons who, through their work in the field of science, have made great contributions to human progress. After the name of each person are stated some of the principal "things" for which he is famous, and page references are given to the books in the list of books preceeding.

The greater part of the bulletins and pamphlets listed under Referencfs to the different units are publications of the United States Government. Where prices are given, the bulletins may be obtained from the *Superintendent of Documents, Washington, D. C.* Where prices are not given, the bulletins may be obtained free by writing to the various departments, bureaus, or services at Washington, D. C., and specifying the exact title and number. The various classes of bulletins supplied by each department, bureau, or service are indicated in the following list:

Bureau of Animal Industry
Circulars
Bureau of Census
Bulletins, Reports
Bureau of Education
Bulletins
Bureau of Fisheries
Documents
Bureau of Mines
Technical Papers
Bureau of Standards
Circulars, Reprints
Children's Bureau
Bulletins
Coast Guard
Bulletins

DEPARTMENT OF AGRICULTURE
Farmers' Bulletins, Agriculture Department Circulars, Agriculture Bulletins, Agriculture Department Reprints, Agriculture Yearbook Separates

DEPARTMENT OF INTERIOR
Bulletins

FOREST SERVICE
Bulletins

GEOLOGICAL SURVEY
Water Supply Papers

PUBLIC HEALTH SERVICE
Reprints, Bulletins, Supplements, Keep-Well Series, Bulletins of the Hygienic Laboratory

SIGNAL OFFICE
Training Pamphlets

WAR DEPARTMENT
Documents

WEATHER BUREAU
Bulletins

A few bulletins and pamphlets listed in the REFERENCES are published by private organizations. The addresses of these organizations are:

Eye-sight Conservation Council Bulletins
The Eye-sight Conservation Council of America, Times Bldg., New York City.

Lick Observatory Circular
Lick Observatory, San Jose, California

Taylor Instrument Companies Pamphlets
The Taylor Instrument Co., Rochester, N. Y.

The Mentor
The Mentor Association, Springfield, Ohio

Yerkes Observatory Circular
Yerkes Observatory, Williams Bay, Wisc.

GENERAL REFERENCES

BODMER, R. Book of Wonders. C. N. Casper and Co., Milwaukee, Wisc.

COMPTON'S PICTURED ENCYCLOPEDIA (10 vols.). F. E. Compton and Co., Chicago

DOWNING, E. R. Our Physical World. University of Chicago Press, Chicago

ENCYCLOPEDIA AMERICANA. Encyclopedia Americana Corporation, New York City

HILL, H. C. The Wonder Book of Knowledge. John C. Winston Co., Chicago.

MARSHALL, L. C. The Story of Human Progress. The Macmillan Company

NELSON'S PERPETUAL LOOSELEAF ENCYCLOPEDIA (12 vols.). Thomas Nelson and Sons, New York City

SLOSSON, E. E. Chats on Science. The Century Company

SLOSSON, E. E. Keeping up with Science. Harcourt, Brace and Company

THE ENCYCLOPAEDIA BRITANNICA (29 vols.). The Encyclopaedia Britannica Co., New York City

THE NEW INTERNATIONAL ENCYCLOPEDIA (23 vols.). Dodd, Mead and Co., New York City

THOMSON, A. J. Outlines of Science (5 vols.). G. P. Putnam's Sons, New York City

WILLIAMS, H. S. The Wonders of Science in Modern Life (10 vols.). Funk and Wagnalls, New York City

WILLIAMS, H. S. The Story of Modern Science (10 vols.). Funk and Wagnalls, New York City

UNIT I: THE EARTH ON WHICH YOU LIVE

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries
2. Baker, R. S. Boys' Second Book of Inventions
3. Ball, R. S. Star-Land
4. Ball, R. S. An Atlas of Astronomy
5. Ball, R. S. The Story of the Heavens
6. Barritt, L. The Dipper as a Guide to First-Magnitude Stars
7. Bond, A. R. The American Boy's Engineering Book
8. Bond, A. R. The Scientific American Boy at School
9. Bowen, E. A. Astronomy by Observation
10. Burns, E. E. The Story of Great Inventions
11. Clark, E. C. Astronomy from a Dipper
12. Collins, A. F. The Book of Stars
13. Collins, A. F. The Boy Astronomer
14. Corbin, T. The Romance of Submarine Engineering
15. Darrow, F. L. The Boys' Own Book of Great Inventions
16. Darrow, F. L. Masters of Science and Invention
17. DuPuy, W. A. Uncle Sam, Wonder Worker
18. Fabre, J. H. The Story Book of Science
19. Fabre, J. H. This Earth of Ours
20. Fisher, E. E. Resources and Industries of the United States
21. Fleming, R. M. Stories from the Early World
22. Forman, S. E. Stories of Useful Inventions
23. Fournier d'Albe, E. E. Wonders of Physical Science
24. Gibson, C. R. Heroes of Science
25. Gibson, C. R. Chemistry and Its Mysteries
26. Griffith, A. M. The Stars and Their Stories
27. Hale, G. E. The Study of Stellar Evolution
28. Hawks, E. The Boys' Book of Astronomy
29. Holden, E. S. Stories of the Great Astronomers
30. Holden, E. S. Real Things in Nature
31. Holland, R. S. Historic Inventions
32. Houston, E. J. The Wonder Book of Light
33. Jacoby, H. Practical Talks by an Astronomer
34. Johnson, G. The Star People
35. Johnson, V. E. Modern Inventions
36. Lane, M. A. L. Triumphs of Science
37. Lodge, Sir Oliver. Pioneers of Science
38. Martin, M. E. The Friendly Stars

39. Martin, M. E. The Ways of the Planets
40. McFee, I. N. Secrets of the Stars
41. McKready, K. A Beginner's Star Book
42. Mitton, G. E. The Children's Book of Stars
43. Olcott, W. T. The Book of the Stars
44. Olcott, W. T. In Starland with a Three-Inch Telescope
45. Olcott, W. T. The Book of the Stars for Young People
46. Overton, G. L. Clocks and Watches
47. Porter, J. G. The Stars in Song and Legend
48. Proctor, M. Stories of Starland
49. Proctor, R. A. A Star Primer
50. Proctor, R. A. Easy Star Lessons
51. Proctor, R. A. The Southern Skies
52. Proctor, R. A. Our Place Among the Infinities
53. Rogers, J. E. Earth and Sky Every Child Should Know
54. Rolt-Wheeler, F. The Polar Hunters
55. Seeley, H. G. The Story of the Earth
56. Seers, A. W. The Earth and Its Life
57. Serviss, G. P. Astronomy with the Naked Eye
58. Serviss, G. P. Around the Year with the Stars
59. Seton, E. T. and Baden-Powell, Sir Robert. Boy Scouts of America: Official Handbook
60. Small, S. A. The Boys' Book of the Earth
61. Tappan, E. M. Makers of Many Things
62. Verrill, A. H. The Ocean and Its Mysteries
63. Washburne, C. W. and H. C. The Story of the Earth
64. Williams, A. How It Works
65. Williams, A. A Book of the Sea
66. Williams, H. S. The Conquest of Sea and Land
67. Woodhull, J. F. Electricity and Its Everyday Uses
68. Wright, H. C. Children's Stories of the Great Scientists

(*B*) Pamphlets and Bulletins

69. Bureau of Standards Circular No. 51. "Measurement of Time and Tests of Timepieces." 15¢.
70. The Mentor. "The Latest Marvels of Astronomy." 35¢.
71. The Yerkes Observatory descriptive circular.
72. The Lick Observatory descriptive circular. 25¢.

The Mentor:

73. "The Earth's Voyage." 35¢.
74. "Keeping Time." 25¢.
75. "Our Planet Neighbors." 25¢.

76. "Calendars and Almanacs." 25¢.
77. "Earthquakes and Volcanoes." 35¢.
78. BUREAU OF STANDARDS CIRCULAR No. 55. "Measurements for the Household." 25¢.

2. GUIDE TO REFERENCES

(*A*) GENERAL

9: (entire). **27:** (104 plates). **30:** 1-43. **56:** (entire). **70:** (entire). (Consult also any elementary textbook on astronomy.)

(*B*) SPECIFIC TOPICS

1. **Constellations.** **6:** (entire). **11.** (entire). **12:** 166-184. **13:** 75-151. **26:** (entire). **33:** 10-17. **34:** (entire). **38:** 177-246. **40:** 200-243. **42:** 148-158. **43:** 5-340. **43:** (entire). **44:** (entire). **49:** (entire). **50:** (entire). **51:** (entire). **53:** 201-244. **57:** 1-170. **58:** (entire). **59:** 107-111.
2. **The Size, Shape, and Movement of the Earth.** **18:** 227-249. **19:** 3-13. **19:** 72-82. **73:** (entire).
3. **Stars.** **3:** 296-325. **12:** 1-28. **13:** 44-74. **28:** 190-210. **33:** 37-46. **38:** (entire). **40:** 1-20. **40:** 182-199. **41:** 9-17. **41:** 22-61. **42:** 135-147. **42:** 159-196. **44:** (entire). **45:** (entire). **47:** (entire). **49:** (entire). **50:** (entire). **51:** (entire). **58:** (entire). **59:** 99-106.
4. **Meteors and Comets.** **3:** 238-296. **4:** Plates 15 and 16. **5:** 336-371. **12:** 112-117. **13:** 211-218. **28:** 159-190. **40:** 135-158. **40:** 169-181. **41:** 93-96. **42:** 103-134. **52:** 71-108. **60:** 92-94. **67:** 333-338.
5. **Nebulas.** **3:** 330-345. **4:** Plates 14. **12:** 118-120. **28:** 241-252. **33:** 27-36. **40:** 158-168. **41:** 17-21. **42:** 197-207.
6. **Sun.** **1:** 163-184. **3:** 1-69. **4:** Plate 17. **12:** 29-45. **13:** 152-163. **18:** 250-256. **28:** 26-57. **40:** 21-43. **41:** 62-69. **42:** 89-102. **60:** 88-90.
7. **Moon.** **3:** 70-125. **4:** Plates 7 and 28-42. **12:** 89-99. **12:** 144-148. **13:** 195-201. **19:** 26-36. **28:** 70-84. **33:** 199-209. **40:** 119-134. **41:** 69-80. **42:** 21-31. **57:** 226-240. **60:** 90-92.
8. **Tides.** **12:** 99-105. **13:** 202. **14:** 165-178. **19:** 306-324. **42:** 29-31. **62:** 66-80. **64:** 452-455. **65:** 416-429.
9. **Planets.** **3:**120-238. **4:** Plates 3 and 11. **13:** 170-181. **28:** 97-159. **33:** 58-68. **33:** 140-151. **39:** (entire). **40:** 79-118. **41:** 83-93. **42:** 48-88. **57:** 187-225. **75:** (entire).
10. **Gravity.** **16:** 13-26. **19:** 14-25. **24:** 107-133.
11. **Time.** **12:** 151-165. **13:** 191-195. **13:** 224-228. **33:** 111-130. **46:** 1-10. **66:** 24-26. **69:** (entire). **74:** (entire). **78:** 126-135.

12. **Seasons.** **4:** Plate 5. **12:** 72-76. **13:** 182-191. **18:** 264-270. **19:** 54-71.
13. **Day and Night.** **18:** 257-264. **19:** 37-54.
14. **Solar System.** **12:** 46-65. **13:** 164-170. **16:** 63-66. **28:** 92-97. **40:** 67-79. **42:** 1-20. **42:** 32-48. **60:** 85-88.
15. **Eclipse of Sun.** **12:** 110-112. **13:** 207-211. **28:** 57-70. **42:** 28-29.
16. **Eclipse of Moon.** **4:** Plate 5. **12:** 107-110. **13:** 204-207. **42:** 26-28.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **History of Astronomy.** **26:** 217-253. **28:** 1-10.
2. **The Origin of Our Present Calendar.** **24:** 134-163. **56:** 168-183. **76:** (entire).
3. **The Story of the Earth.** **19:** (entire). **21:** (entire). **40:** 44-65. **53:** 3-197. **55:** (entire). **56:** 7-32. **58:** 293-403. **60:** 1-213. **63:** 3-21.
4. **Modern Astronomical Observatories.** **27:** (entire). **36:** 14-32. **71:** (entire). **72:** (entire).
5. **The Ocean.** **1:** 124-136. **18:** 358-368. **19:** 278-288. **62:** 16-36.
6. **Photographing the Heavenly Bodies.** **12:** 185-188. **33:** 81-110.
7. **The Sun as a Source of Power.** **1:** 172-178. **2:** 153-172. **35:** 166-173.
8. **How to Make and Use Star Finders.** **7:** 70-86. **13:** 15-28.
9. **Formation of Soil.** **20:** 5-18. **53:** 44-71. **56:** 25-32.
10. **Star Legends and Myths.** **26:** (entire). **43:** (entire). **47:** (entire). **57:** 1-170.
11. **How to Make a Simple Telescope.** **15:** 376-377.
12. **Astronomical Telescopes.** **3:** 87-97. **3:** 215-220. **13:** 29-44. **13:** 219-224. **16:** 3-12. **16:** 58-63. **16:** 135-139. **24:** 188-213. **28:** 10-26. **31:** 53-69. **32:** 97-111. **33:** 170-183. **41:** 97-115.
13. **Primitive Methods of Keeping Time.** **1:** 51-59. **10:** 9-18. **16:** 3-12. **22:** 211-226. **23:** 50-64. **46:** 11-24. **64:** 410-413.
14. **How to Make Simple Devices for Keeping Time.** **8:** 219-233. **33:** 69-80.
15. **The Composition of Stars.** **3:** 325-330. **25:** 217-233.
16. **Earthquakes and Volcanoes.** **17:** 71-83. **18:** 322-328. **18:** 337-343. **19:** 96-139. **60:** 253-272. **77:** (entire).
17. **Glaciers.** **19:** 237-249. **53:** 98-109.
18. **Clocks and Watches.** **1:** 56-59. **10:** 9-18. **46:** 99-116. **61:** 64-72. **64:** 413-430. **78:** 126-135.

19. **Distances between Heavenly Bodies and How They Are Measured.** **3**: 16-18. **3**: 310-318. **33**: 152-160. **38**: 148-161.

20. **Locating the Visible Planets.** (See references under "Planets.")

21. **The Milky Way.** **57**: 171-181.

22. **Discoverers and Inventors in Science.** (See also page 570.)
Clark, Alvan. **16**: 135-139.
Einstein, Albert. **16**: 18-26.
Galilei, Galileo. **10**: 9-18. **15**: 367-372. **16**: 3-12. **31**: 53-69. **23**: 50-64. **24**: 76-106. **33**: 47-57.
Herschel, William and Caroline. **16**: 58-63. **24**: 188-213. **37**: 274-293.
La Place, Pierre de. **16**: 63-66.
Newton, Isaac. **16**: 13-17. **24**: 107-133.
The Earliest Astronomers. **23**: 11-22. **56**: 169-183.

UNIT II: CLIMATE AND WEATHER

1. REFERENCES

(*A*) Books

1. Archibald, D. The Story of the Earth's Atmosphere
2. Bolton, H. C. Evolution of the Thermometer (1592-1743)
3. Bond, A. R. The American Boys' Engineering Book
4. DuPuy, W. A. Uncle Sam's Modern Miracles
5. Fabre, J. H. This Earth of Ours
6. Fabre, J. H. The Story Book of Science
7. Fournier d'Albe, E. E. Wonders of Physical Science
8. Haskin, F. J. The American Government
9. Harrington, E. S. All about the Weather
10. Houston, E. J. The Wonder Book of the Atmosphere
11. Longstreth, T. M. Reading the Weather
12. McAdie, A. Wind and Weather
13. Miall, L. C. The Early Naturalists: Their Lives and Work
14. Philip, J. C. The Romance of Modern Chemistry
15. Rogers, J. E. Earth and Sky Every Child Should Know
16. Rolt-Wheeler, F. The Boy with the U. S. Weather-Men
17. Seers, A. W. The Earth and Its Life
18. Shaler, N. S. Aspects of the Earth
19. Williams, A. How It Works
20. Williams, A. Thinking It Out

(*B*) Pamphlets and Bulletins

Farmers' Bulletins:

21. No. 104. "Notes on Frost." 5¢.
22. No. 842. "Modern Methods of Protection against Lightning." 5¢.
23. No. 1096. "Frost and the Prevention of Damage by It." 5¢.
24. Agriculture Bulletin, No. 821. "Frost Protection in Lemon Orchards." 10¢.

U. S. Weather Bureau Bulletins:

25. No. 42. "Weather Forecasting." 5¢.
26. No. 41. "Forecasting Frost in the North Pacific States." 10¢.
27. No. 80. "Instruction to Storm-warning Display Men of the Weather Bureau." 5¢.
28. "The Weather Bureau" (free)
29. "Explanation of the Weather Maps" (free)
30. "Wind-Barometer Table" (free)
31. "The Daily Weather Map with Explanations." 5¢.
32. Department of Agriculture Yearbook Separate (1915). "Stories of the Atmosphere." 5¢.
33. Department of Agriculture Yearbook Separate No. 635. (1914) "Story of the Thermometer and Its Uses in Agriculture." 5¢.

Taylor Instrument Companies Pamphlets:

34. "Practical Hints for Amateur Weather Forecasters." 10¢.
35. "The Barometer Book." 10¢.
36. "The Barometer as the Foot-Rule of the Air." 10¢.
37. "Humidity: Its Effect on Our Health and Comfort." 10¢.
38. "The Mountains of Cloudland and Rainfall." 10¢.
39. "The Thermometer and Its Family Tree." 10¢.
40. "Weather and Weather Instruments." 50¢.
41. The Mentor. "The Weather." 25¢.

Bureau of Standards Circulars:

42. No. 75. "Safety for the Household." 25¢.
43. No. 55. "Measurements for the Household."
44. Weather Bulletin. "Instructions for Volunteer Observers." 5¢.

2. GUIDE TO REFERENCES

(*A*) General

6: (entire). **10:** (entire). **12:** (entire). **16:** (entire). **25:** (entire). **32:** (entire). **41:** (entire). (Consult also any elementary textbook on physiography.)

(*B*) Specific Topics

1. **Temperature and Thermometers.** **1:** 31-63. **2:** (entire). **11:** 86-98. **13:** 244-248. **33:** (entire). **39:** (entire).
2. **Clouds.** **6:** 181-186. **9:** 76-92. **11:** 65-75. **14:** 180-192. **38:** (entire). **40:** 103-114.
3. **Rain, Snow, Dew, Frost, Sleet, and Hail.** **1:** 106-124. **6:** 192-200. **9:** 73-76. **9:** 92-98. **9:** 166-173. **11:** 99-115. **40:** 123-127.
4. **Air Pressure and the Barometer.** **1:** 25-31. **7:** 65-79. **9:** 33-48. **20:** 217-220. **20:** 225-226. **35:** (entire). **36:** (entire).
5. **Wind.** **1:** 64-93. **9:** 48-59. **11:** 76-85. **18:** 212-222. **40:** 133-143.
6. **"Highs" and "Lows."** **1:** 125-138. **9:** 99-146. **11:** 42-63.
7. **The Weather Bureau and Weather Forecasting.** **4:** 28-41. **8:** 227-236. **9:** 203-210. **25:** (entire). **28:** (entire). **29:** (entire). **30:** (entire). **31:** (entire). **34:** (entire). **44:** (entire).
8. **Weather Signals.** **11:** 193-195. **27:** (entire).
9. **Climate.** **5:** 223-236. **17:** 199-208.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **How to Make an Anemometer.** **3:** 295-298.
2. **Frost Protection.** **16:** 180-210. **21:** (entire). **23:** (entire). **24:** (entire). **26:** (entire).
3. **Hurricanes.** **11:** 133-138. **16:** 228-311. **18:** 226-256.
4. **Land and Sea Breezes.** **18:** 226-227.
5. **Lightning and Protection against It.** **1:** 159-162. **9:** 180-186. **16:** 312-336. **22:** (entire). **40:** 117-120. **42:** 45-53.
6. **How to Make a Rain Gauge.** **3:** 298-300.
7. **Tornadoes.** **9:** 156-165. **11:** 129-132. **16:** 255-279. **18:** 226-256.
8. **Weather Lore and Weather Proverbs.** **11:** 175-192. **40:** 6-23.
9. **Interesting Temperatures.** **43:** 67.
10. **Thunderstorms.** **1:** 159-162. **9:** 174-186.
11. **Humidity and Its Measurement.** **9:** 66-92. **37:** (entire). **43:** 108-117.
12. **Manufacture of Thermometers.** **2:** (entire). **39:** (entire). **40:** 75-90.
13. **Home Uses of the Thermometer.** **43:** 38-55.
14. **Weather Instruments.** **11:** 147-156. **19:** 325-331. **35:** (entire). **36:** (entire). **40:** (entire). **43:** 118-121.
15. **Composition of the Air.** **15:** 35-43.

16. How to Build an Electric Weather Vane. **3**: 288-294.

17. Discoverers and Inventors in Science. (See also page 570.)
Fahrenheit, Gabriel. **2**: 66-79.
Franklin, Benjamin. **7**: 109-113.
Galilei, Galileo. **7**: 65-79. **2**: 14-25.
Guericke, Otto von. **7**: 80-88.
Torricelli. **7**: 65-79.

UNIT III: PROVIDING A GOOD FOOD SUPPLY

1. REFERENCES

(*A*) Books

1. Abbot, G. G. Everyday Mysteries
2. Bailey, E. H. S. and H. S. Food Products from Afar
3. Baker, R. S. Boy's Second Book of Inventions
4. Bassett, S. W. The Story of Sugar
5. Brooks, E. C. The Story of Corn
6. Carpenter, F. O. Foods and Their Uses
7. Collins, A. F. Wonders of Chemistry
8. Collins, A. F. The Amateur Mechanic
9. Conley, E. Nutrition and Diet
10. Conn, H. W. Bacteria, Yeasts, and Molds in the Home
11. Crissey, F. The Story of Foods
12. Earle, A. M. Home Life in Colonial Days
13. Fabre, J. H. The Wonder Book of Chemistry
14. Fisher, E. E. Resources and Industries of the United States
15. Gillett, L. H. Food for Health's Sake
16. Green, M. E. Food Products of the World
17. Greer, E. Food—What It Is and Does
18. Haskin, F. J. The American Government
19. Kellogg, J. H. The Battle Creek Sanitarium Diet List
20. Lipman, J. G. Bacteria in Relation to Country Life
21. Mills, J. C. Searchlights on Some American Industries
22. Morris, C. Home Life in All Lands, Book I
23. Morris, C. Home Life in All Lands, Book II
24. Mowry, W. A. and A. M. American Inventions and Inventors
25. Newbigin, M. I. Tillers of the Ground
26. O'Shea, M. V. and Kellog, J. H. Making the Most of Life
27. Pack, A. N. Our Vanishing Forests
28. Reynolds, M. J. How Man Conquered Nature
29. Rocheleau, W. F. Great American Industries, Vol. II

30. Rocheleau, W. F. Great American Industries, Vol. III
31. Sanford, A. H. The Story of Agriculture in the United States
32. Surface, G. T. The Story of Sugar
33. Tappan, E. M. Travelers and Traveling
34. Tappan, E. M. The Farmer and His Friends
35. Willard, F. and Gillett, L. H. Dietetics for High Schools
36. Williams, H. S. Tribute From the Animal World
37. Wright, S. The Romance of the World's Fisheries

(*B*) Pamphlets and Bulletins

Farmers' Bulletins:

38. No. 85. "Fish as Food." 5¢.
39. No. 256. "Preparation of Vegetables for the Table." 5¢.
40. No. 291. "Evaporation of Apples." 5¢.
41. No. 477. "Sorghum Sirup Manufacture." 5¢.
42. No. 487. "Cheese and Its Economical Uses in the Diet.'
43. No. 535. "Sugars and Its Value as Food." 5¢.
44. No. 565. "Corn-Meal as Food, and Ways of Using It."
45. No. 653. "Honey and Its Uses in the Home." 5¢.
46. No. 805. "Drainage of Irrigated Farms." 5¢.
47. No. 817. "Cereal Foods." 5¢.
48. No. 824. "Foods Rich in Proteins." 5¢.
49. No. 841. "Drying Fruits and Vegetables in the Home." 5¢.
50. No. 876. "Making Butter on the Farm." 5¢.
51. No. 879. "Home Storage of Vegetables." 5¢.
52. No. 712. "School Lunches." 5¢.
53. No. 808. "What the Body Needs." 5¢.
54. No. 881. "Preservation of Vegetables." 5¢.
55. No. 1313. "Good Proportions in Diet." 5¢.
56. No. 1359. "Milk and Its Uses in the Home." 5¢.
57. No. 1366. "Production of Maple Sirup and Sugar." 5¢.
58. No. 1374. "Care of Food in the Home." 5¢.
59. No. 1383. "Food Values and Body Needs." 10¢.
60. No. 976. "Cooling Milk and Cream on the Farm." 5¢.
61. No. 984. "Farm and Home Drying of Fruits and Vegetables." 5¢.
62. No. 1034. "Growing Sugar Cane for Sirup." 5¢.
63. No. 1078. "Harvesting and Storing Ice on the Farm." 5¢.
64. No. 1109. "Preserving Eggs."
65. No. 1136. "Baking in the Home." 10¢.
66. No. 1186. "Pork on the Farm; Killing, Curing, and Canning." 10¢.
67. No. 1191. "Making American Cheese on the Farm." 5¢.
68. No. 1236 "Corn and Its Uses as Food." 5¢.

Agriculture Bulletins:

69. No. 467. "Food Values and Uses of Poultry." 5¢.
70. No. 468. "Potatoes, Sweet Potatoes, and Other Starchy Roots as Foods." 5¢.
71. No. 469. "Fats and Their Economical Use in the Home." 5¢.
72. No. 471. "Eggs and Their Value as Food." 5¢.
73. No. 637. "Methods of Calculating Economical Balanced Ration." 5¢.
74. No. 995. "The Beet-Sugar Industry in the U. S." 20¢.
75. No. 1141. "Evaporation of Fruits."

Agriculture Department Circulars:

76. No. 129. "Milk for the Family." 5¢.
77. No. 300. "Commercial Cuts of Meat." 5¢.
78. Experiment Station Bulletin No. 28. "Chemical Composition of American Food Materials." 10¢.
79. Agriculture Year Book Separate No. 745. "Service of Cold Storage in Conservation of Food Stuffs." 5¢.
80. Bureau of Fisheries Document No. 976. "Fishery Industries of the U. S." 25¢.
81. Children's Bureau Bulletin No. 35. "Milk, the Indispensable Food for Children." 5¢.
82. Public Health Service Reprint No. 85. "Methods and Standards for the Production of Certified Milk." (Free.)
83. Public Health Service Bulletin No. 102. "A Home-made Milk Refrigerator." 5¢.
84. Bureau of Standards Circular No. 55. "Measurements for the Household." 25¢.

2. GUIDE TO REFERENCES

(*A*) General

2: 112-123. **4**: 97-120. **6**: (entire). **9**: (entire). **11**: (entire). **15**: (entire). **34**: (entire).

(*B*) Specific Topics

1. **Kinds of Food Stuffs and Their Use by the Body.** **6**: 5-24. **9**: 18-35. **16**: 7-14. **35**: 28-58.
2. **Sources of Foods.** **2**: 3-14. **16**: 1-5. **23**: 133-213. **24**: 131-143. **25**: 115-140.

3. **Selection of a Balanced Ration.** **9**: 43-102. **19**: (entire). **35**: 15-27. **35**: 77-147. **52**: (entire). **53**: (entire). **55**: (entire). **59**: (entire). **73**: (entire). **78**: (entire).
4. **Methods of Cooking Foods.** **6**: 190-196. **39**: (entire). **44**: (entire). **47**: (entire). **48**: (entire). **64**: (entire).
5. **Preservation of Food.** **1**: 34-41. **6**: 188-196. **10**: 139-196. **16**: 431-446. **54**: (entire). **58**: (entire). **64**: (entire).
6. **Plant Growth and Sunshine.** **1**: 179-184. **13**: 323-344.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Early Methods of Producing, Storing, and Cooking Foods.** **12**: 108-165. **24**: 104-110. **25**: 37-49. **36**: 1-8.
2. **The Production and Preparation of Food from Wheat, Corn, Rice, and Other Cereals.** **2**: 125-150. **5**: (entire). **6**: 24-67. **6**: 30-54. **9**: 108-127. **11**: 36-86. **14**: 33-55. **16**: 163-175. **29**: 124-178. **34**: 28-44. **68**: (entire).
3. **Dairy Products and How They Are Made.** **2**: 61-79. **6**: 136-144. **9**: 180-201. **11**: 146-186. **16**: 103-130. **20**: 416-430. **42**: (entire). **50**: (entire). **56**: (entire). **60**: (entire). **67**: (entire). **76**: (entire). **81**: (entire). **82**: (entire).
4. **Fishing and the Sea-Food Industry.** **2**: 254-270. **6**: 126-135. **11**: 247-312. **14**: 91-99. **16**: 55-82. **18**: 267-272. **36**: 153. **37**: (entire). **38**: (entire). **80**: (entire).
5. **Foods of Many Lands.** **2**: 151-175. **2**: 271-283. **6**: 1-5. **6**: 203-210. **22**: 13-49. **25**: 50-76. **28**: 84-108.
6. **Sugars and Their Manufacture** (Cane, Beet, Maple, and Sorghum). **2**: 176-190. **4**: (entire). **6**: 86-100. **7**: 114-118. **11**: 187-193. **11**: 428-441. **14**: 52-62. **16**: 239. **21**: 61-84. **27**: 67-74. **29**: 51-88. **32**: (entire). **34**: 22-27. **34**: 58-65. **41**: (entire). **43**: (entire). **45**: (entire). **57**: (entire). **62**: (entire). **74**: (entire).
7. **Fruits and Nuts.** **2**: 25-41. **2**: 80-124. **2**: 245-253. **6**: 67-74. **9**: 145-151. **11**: 87-124. **11**: 412-427. **14**: 63-71. **16**: 217-238. **25**: 76-115. **34**: 15-21. **34**: 45-57.
8. **Vegetables and Their Use as Food.** **9**: 129-144. **11**: 125-145. **14**: 71-76. **51**: (entire).
9. **Poultry and Poultry Products.** **9**: 174-179. **11**: 194-200. **16**: 47-53. **36**: 76-98. **69**: (entire). **72**: (entire).
10. **Fats—Animal and Vegetable.** **2**: 42-60. **11**: 238-246. **71**: (entire).
11. **Vitamines.** **1**: 110-115. **35**: 71-76.

12. **The Inventor and the Food Problem.** **3**: 173-206.
13. **Beverages.** **2**: 191-205. **2**: 227-244. **6**: 147-182. **9**: 152-155. **11**: 366-411.
14. **Spices and Condiments.** **11**: 442-456. **16**: 83-107.
15. **The Meat Packing Industry** (Cattle, Hogs, Sheep). **6**: 109-123. **6**: 102-125. **9**: 156-173. **11**: 201-237. **14**: 76-88. **16**: 15-42. **30**: 100-126. **36**: 60-75. **36**: 177-190. **77**: (entire).
16. **Commercial Methods of Canning Foods.** **11**: 313-340.
17. **Killing, Curing, and Canning Pork.** **66**: (entire).
18. **Experiments with Molds, Bacteria, and Yeasts.** **10**: 269-285.
19. **Ice and the Refrigeration of Food.** **8**: 157-165. **10**: 148-156. **32**: 26-35. **63**: (entire). **79**: (entire). **83**: (entire).
20. **Micro-Organisms Which Spoil Food** (Bacteria, Yeasts, and Molds). **10**: 1-85. **10**: 100-138.
21. **Pasteurization of Milk.** **10**: 182-196. **20**: 388-394.
22. **Uses of Thermometers in Cooking.** **84**: 38-55.
23. **Preserving Foods by Drying.** **10**: 139-148. **11**: 341-357. **40**: (entire). **49**: (entire). **61**: (entire).
24. **Potato—Irish and Sweet.** **16**: 193-199. **34**: 9-14. **49**: (entire). **70**: (entire).
25. **The Beginning of Agriculture.** **25**: 37-49.
26. **Irrigation, Drainage, and Dry Farming.** **14**: 13-26. **25**: 13-26. **31**: 332-344. **46**: (entire).
27. **Condensed Foods.** **11**: 358-365. **16**: 108-115.

UNIT IV: OBTAINING A GOOD WATER SUPPLY

1. REFERENCES

(*A*) Books

1. ABBOTT, C. G. Everyday Mysteries
2. ALLEN, J. K. Sanitation in the Modern Home
3. BASHORE, H. B. The Sanitation of a Country House
4. BOND, A. R. On the Battlefront of Engineering
5. BOND, A. R. With Men Who Do Things
6. CORFIELD, W. H. Sewerage and Sewage Utilization
7. CARPENTER, F. G. How the World is Housed
8. COLLINS, A. F. Wonders of Chemistry
9. COLLINS, A. F. The Amateur Mechanic
10. FABRE, J. H. This Earth of Ours

11. GARNETT, W. A Little Book on Water Supply
12. KNOX, G. D. All About Engineering
13. LANE, M. A. L. Triumphs of Science
14. LIPMAN, J. G. Bacteria in Relation to Country Life.
15. LYNDE, C. J. Home Water Works
16. PRUDDEN, T. M. Drinking Water and Ice Supplies and Their Relation to Health and Disease
17. ROGERS, J. E. Earth and Sky Every Child Should Know
18. WILLIAMS, A. How It Works
19. WILLIAMS, A. The Romance of Modern Engineering
20. WILLIAMS, A. Thinking It Out

(*B*) PAMPHLETS AND BULLETINS

FARMERS' BULLETINS:

21. No. 941. "Water Systems for Farm Homes." 10¢.
22. No. 1227. "Sewage and Sewerage of Farm Homes." 5¢.
23. No. 1426. "Farm Plumbing." 10¢.
24. AGRICULTURE YEAR BOOK SEPARATE No. 712. "Sewage Disposal on the Farm." 5¢.
25. DEPARTMENT OF INTERIOR BULLETIN No. 257. "Well-drilling Methods." 15¢.
26. PUBLIC HEALTH SERVICE SUPPLEMENT No. 39. "Factors Governing the Protection and Selection of Sources of Water Supply." 5¢.
27. PUBLIC HEALTH SERVICE REPORT REPRINT No. 580. "Treatment of Disposal of Sewage." 10¢.
28. PUBLIC HEALTH SERVICE REPORT REPRINT No. 397. "Drinking Fountains." 5¢.
29. PUBLIC HEALTH SERVICE REPRINT No. 76. "The Necessity for Safe Water Supplies in the Control of Typhoid Fever." 5¢.

PUBLIC HEALTH SERVICE BULLETINS:

30. No. 7. "The Sanitary Privy." 5¢.
31. No. 70. "Good Water for Farm Homes."
32. No. 89. "A Sanitary Privy System for Unsewered Towns and Villages."
33. No. 101. "Studies of the Methods for the Treatment and Disposal of Sewage." 25¢.
34. GEOLOGICAL SURVEY WATER-SUPPLY PAPER No. 416. "The Divining Rod."

BUREAU OF STANDARDS CIRCULARS:

35. No. 55. "Measurements for the Household." 25¢.
36. No. 75. "Safety for the Household." 25¢.

2. GUIDE TO REFERENCES

(*A*) General

11: 1-100.

(*B*) Specific Topics

1. **The Cycle of Water in Nature.** **15:** 27-35. **16:** 6-37. **17:** 51-58.
2. **Sources of Water Supply.** **10:** 264-277. **13:** 138-146. **15:** 36-67. **19:** 366-377.
3. **Locating and Building Wells.** **3:** 29-46. **11:** 57-66. **15:** 36-59. **16:** 78-100. **25:** (entire). **34:** (entire).
4. **Supplying Water by the Force of Gravity.** **15:** 120-131.
5. **Pumps and How They Work.** **9:** 57-60. **15:** 68-119.
6. **Plumbing.** **2:** 169-82. **15:** 244-255. **23:** (entire).
7. **Preventing the Pollution of the Water Supply.** **3:** 47-70. **14:** 61-76. **14:** 90-98. **16:** 54-77. **26:** (entire). **29:** (entire).
8. **Purification of Water Supplies.** **8:** 26-28. **9:** 47-49. **11:** 78-86. **14:** 77-89. **16:** 101-114.
9. **Hot Water Supply.** **2:** 183-192. **18:** 386-391. **36:** 73-75.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Centrifugal Pumps.** **20:** 146-148.
2. **Hydraulic Rams.** **9:** 105-110. **15:** 181-192. **20:** 204-208.
3. **Pneumatic House-System of Water Supply.** **9:** 51-56. **15:** 132-146.
4. **Aqueducts.** **4:** 41-68. **5:** 123-136. **11:** 12-57.
5. **Famous Water Supply of Great Cities.** **4:** 41-68. **5:** 123-136. **7:** 325-331. **11:** 19-21. **11:** 105-131. **12:** 106-122. **19:** 55-82.
6. **Power Appliances for Distributing Water.** **15:** 159-230.
7. **Sewage and Sewage Disposal.** **6:** (entire). **14:** 103-124. **22:** (entire). **24:** (entire). **27:** (entire). **30:** (entire). **32:** (entire). **33:** (entire).
8. **Drinking Fountains.** **28:** (entire).
9. **The Properties and Composition of Water.** **1:** 1-30.
10. **The Farm Water Supply.** **21:** (entire). **30:** (entire). **31:** (entire).
11. **Obtaining Water in Foreign Lands.** **7:** 317-325. **11:** 22-66.
12. **Water Meters.** **35:** 102-107.

UNIT V: KEEPING IN GOOD PHYSICAL CONDITION

1. REFERENCES

(*A*) Books

1. Allen, J. K. Sanitation in the Modern Home
2. Camp, Walter. The Book of Sports and Games
3. Chapin, H. D. Health First, the Fine Art of Living
4. Cole, N. B. and Ernst, C. H. First Aid for Boys
5. Collins, A. F. The Book of Stars
6. Conley, E. Nutrition and Diet
7. Dulles, C. W. Accidents and Emergencies
8. Fabre, J. H. The Wonder Book of Chemistry
9. Fisher, I. and Lusk, E. L. How to Live
10. Gibson, C. R. Chemistry and Its Mysteries
11. Godinez, F. L. The Lighting Book
12. Houston, E. J. The Wonder Book of Light
13. Howell, W. H. The Human Machine
14. Hutchinson, W. Community Hygiene
15. Hutchinson, W. Exercise and Health
16. Kellogg, J. H. The Itinerary of a Breakfast
17. Lynch, C. American Red Cross Textbook on First Aid and Relief Columns
18. McLaughlin, A. J. Personal Hygiene
19. Moody, C. S. Backwoods Surgery and Medicine
20. O'Shea, M. V. and Kellogg, J. H. Making the Most of Life
21. Prudden, T. M. The Story of the Bacteria
22. Towne, R. S. Your Teeth
23. Williams, A. How It Works

(*B*) Pamphlets and Bulletins

Public Health Service—Keep Well Series:

24. No. 11. "Malnutrition." 5¢.
25. No. 13. "Good Teeth." 5¢.
26. No. 5. "The Safe Vacation." 5¢.
27. No. 3. "How to Avoid Tuberculosis." 5¢.
28. No. 2. "Adenoids." 5¢.
29. No. 1. "The Road to Health." 5¢.
30. Eye-Sight Conservation Council Bulletin No. 4. 25¢.

Public Health Service Supplements:

31. No. 7. "Shower Baths for Country Houses." 5¢.
32. No. 24. "Exercise and Health." 5¢.
33. No. 36. "What to Do to Become Physically Fit."

Public Health Service Reprints:

34. No. 325. "Vitamines and Nutritional Diseases." 5¢.
35. No. 707. "Good Teeth."
36. No. 753. "Adenoids."

37. U. S. Coast Guard Bulletin. "Directions for Restoring the Apparently Drowned." 5¢.

38. Bureau of Standards Circular No. 75. "Safety for the Household." 25¢.

2. GUIDE TO REFERENCES

(*A*) General

3: (entire). **18:** (entire). **29:** (entire). **33:** (entire).

(*B*) Specific Topics

Note: Only a few references to specific topics are listed here. Further study of these topics can be carried out by reference to any standard text books on Physiology or Hygiene.

1. **The Cells of the Human Body.** **21:** 1-13.
2. **Digestion and Assimilation of Food.** **3:** 116-138. **6:** 36-42. **13:** 7-19. **16:** (entire). **24:** (entire).
3. **The Circulation of the Blood.** **13:** 29-41.
4. **Respiration.** **8:** 70-82. **8:** 109-123. **10:** 143-157. **13:** 20-28. **27:** (entire).
5. **Baths and the Bathroom.** **1:** 210-237. **31:** (entire).
6. **Exercise.** **9:** 89-102. **15:** (entire). **19:** 63-120. **32:** (entire).
7. **Sleep.** **9:** 102-105. **19:** 202-217.
8. **Teeth.** **9:** 78-88. **22:** (entire). **25:** (entire). **35:** (entire).
9. **The Care of the Eyes, and Correct Lighting.** **5:** 127-131. **11:** 1-7. **12:** 127-139. **13:** 53-63. **23:** 246-252. **30:** (entire).
10. **First Aid.** **4:** (entire). **7:** (entire). **17:** (entire). **19:** (entire). **26:** (entire). **38:** 118-124.
11. **Tobacco and Its Effect upon the Body.** **9:** 250-271. **19:** 165-182.
12. **The Effect of Alcohol on the Human Machine.** **9:** 227-249. **19:** 148-164.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Vitamines and Disease. 34:** (entire).
2. **Adenoids. 28:** (entire). **36:** (entire).
3. **Sports and Games. 2:** (entire).
4. **Accident Prevention. 17:** 164-174.
5. **Climate and Health. 3:** 172-191.
6. **Fractures, Sprains, and Dislocations. 4:** 62-72. **4:** 135-155. **17:** 70-89. **19:** 9-26.
7. **Burns, Frostbites, and Sunstrokes. 4:** 54-61. **4:** 84-90. **17:** 117-127.
8. **Wounds and Cuts. 4:** 34-53. **17:** 90-116. **19:** 29-43.
9. **Drowning and Artificial Respiration. 4:** 156-167. **17:** 128-139. **19:** 43-48. **37:** (entire).
10. **Bandages and Carriers. 4:** 101-134. **17:** 36-61.
11. **Shocks and Fainting. 4:** 22-33. **17:** 62-69.
12. **Home and Camp Medicine Chests. 4:** 191-193. **17:** 161-163. **19:** 93-99.
13. **Preventing Infections. 4:** 78-83. **17:** 27-30.
14. **Snake Bites. 19:** 73-89.
15. **Camp Diseases and Care. 19:** 51-70.
16. **How to Carry Injured Persons. 17:** 191-197.

UNIT VI: SELECTING AND CARING FOR OUR CLOTHING

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries
2. Allen, J. K. Sanitation in the Modern Home
3. Bassett, S. W. The Story of Leather
4. Bassett, S. W. The Story of Silk
5. Brooks, E. C. The Story of Cotton
6. Browne, E. A. Rubber
7. Chamberlain, J. F. How We Are Clothed
8. Clarke, C. R. Boys' Book of Chemistry
9. Cochrane, R. The Romance of Industry and Invention
10. Collins, A. F. Wonders of Chemistry
11. Cooke, A. O. A Visit to a Woolen Mill
12. Cooke, A. O. A Visit to a Cotton Mill
13. Cooke, A. O. A Day with the Leather Workers

14. Crabtree, J. H. The Cotton Industry from Raw Cotton to Woven Cloth
15. Curtis, A. T. The Story of Cotton
16. Darrow, F. L. The Boys' Own Book of Science
17. DuPuy, W. A. Uncle Sam, Wonder Worker
18. Darrow, F. L. Masters of Science and Invention
19. Earle, A. M. Home Life in Colonial Days
20. Fabre, J. H. The Story Book of Science
21. Fisher, E. E. Resources and Industries of the United States
22. Fisher, I. and Lusk, E. L. How to Live
23. Gibson, C. R. The Romance of Modern Manufacture
24. Goddard, D. Eminent Engineers
25. Hale, E. E. Stories of Invention
26. Holland, R. S. Historic Inventions
27. Iles, G. Leading American Inventors
28. Jenkins, O. P. Interesting Neighbors
29. Kinne, H., and Cooley, A. M. Shelter and Clothing
30. Mills, J. C. Searchlights on Some American Industries
31. Morris, C. Home Life in All Lands, Vol. I
32. Mowry, W. A. and A. M. American Inventions and Inventors
33. Parkman, M. R. Conquests of Inventions
34. Prudden, T. M. The Story of the Bacteria
35. Quennell, M. and C. H. B. Everyday Life in the New Stone, Bronze, and Early Iron Ages
36. Reynolds, M. J. How Man Conquered Nature
37. Rocheleau, W. F. Great American Industries, Vol. II
38. Rocheleau, W. F. Great American Industries, Vol. III
39. Tappan, E. M. The Farmer and His Friends
40. Tappan, E. M. Makers of Many Things
41. Williams, H. S. Science and Industry
42. Williams, H. S. Tribute from the Animal World
43. Williams, A. How It Is Made

(*B*) Pamphlets and Bulletins

Farmers' Bulletins:

44. No. 669. "Fiber Flax." 5¢.
45. No. 861. "Removal of Stains from Clothing and Other Textiles." 5¢.
46. No. 1055. "Country Hides and Skins, Skinning, Caring, and Marketing." 10¢.
47. No. 1089. "Selection and Care of Clothing." 5¢.

48. No. 1099. "Home Laundering." 5¢.
49. No. 1183. "The Care of Leather." 5¢.
50. No. 1203. "The Angora Goat." 5¢.
51. No. 1319. "Cotton Dusting Machinery." 5¢.
52. No. 1334. "Home Tanning of Leather and Small Fur Skins." 5¢.
53. No. 1353. "Clothes Moths and Their Control." 10¢.
54. AGRICULTURE DEPARTMENT CIRCULAR No. 135. "Maintenance of the Fur Supply." 10¢.
55. BUREAU OF CENSUS BULLETIN No. 156. "Cotton Production and Distribution (1923-24)." 10¢.
56. DEPARTMENT OF AGRICULTURE BULLETIN No. 206. "The Wool Grower and the Wool Trade." 15¢.
57. AGRICULTURE YEARBOOK SEPARATE No. 628. "Hemp." 15¢.
58. BUREAU OF STANDARDS CIRCULAR No. 70. "Materials for the Household." 25¢.

THE MENTOR:

59. "The Story of Fur." 35¢.
60. "The Story of Rubber." 25¢.

2. GUIDE TO REFERENCES

(*A*) GENERAL

1: (entire). **7:** (entire). **22:** 14-17. **9:** 81-101. **29:** 97-367. **47:** (entire).

(*B*) SPECIFIC TOPICS

1. **Kinds and Sources of Fibers.** **36:** 109-125.
2. **Hard and Soft Water.** **10:** 22-23. **58:** 192-193.
3. **Cleansing Action of Soap.** **8:** 151-153. **10:** 23-24.
4. **Home Laundering and Cleaning.** **2:** 83-95. **48:** (entire). **58:** 195-197.
5. **Removing Spots and Stains.** **16:** 136-145. **45:** (entire). **53:** 162.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Producing Cotton and Manufacturing Cotton Goods.** **5:** (entire). **7:** 39-59. **12:** (entire). **14:** (entire). **15:** (entire). **17:** 1-9. **20:** 71-76. **21:** 109-117. **24:** 61-69. **25:** 219-236. **26:** 84-110. **32:** 148-157. **37:** 89-123. **39:** 91-97. **40:** 82-91. **41:** 1-31. **51:** (entire). **55:** (entire).

2. **Production and Preparation of Wool.** **7**: 57-79. **11**: (entire). **19**: 187-211. **20**: 64-66. **21**: 104-108. **32**: 158-163. **42**: 44-48. **42**: 53-59. **50**: (entire). **56**: (entire).
3. **The Silk Worm and Its Product.** **4**: (entire). **20**: 93-107. **28**: 69-83. **40**: 92-101. **42**: 131-152.
4. **Flax and Hemp.** **20**: 67-70. **21**: 117-118. **39**: 86-90. **44**: (entire). **57**: (entire).
5. **Manufacture of Cloth from Fibers.** **1**: 104-111. **5**: 39-131. **5**: 223-279. **21**: 109-117. **23**: 34-104. **33**: 38-48. **36**: 109-125. **41**: 66-74.
6. **How Hides Are Made into Wearing Apparel.** **1**: 146-162. **3**: (entire). **7**: 99-107. **13**: (entire). **21**: 100-104. **30**: 165-207. **32**: 164-172. **38**: 81-99. **40**: 16-24. **40**: 73-81. **41**: 91-112. **42**: 99-116. **47**: (entire). **49**: (entire). **52**: (entire). **58**: 145-151.
7. **Furs.** **42**: 99-116. **54**: (entire). **59**: (entire).
8. **Manufacture of Rubber Goods.** **6**: 1-88. **7**: 107-129. **10**: 124-127. **27**: 176-218. **33**: 110-134. **30**: 131-164. **40**: 6-15. **43**: 180-192. **60**: (entire).
9. **Making Soap.** **1**: 42-50. **8**: 153-155. **16**: 119-126. **43**: 89-92. **58**: 193-195.
10. **Washing Clothes with Machinery.** **7**: 204-209. **23**: 105-113.
11. **History of Clothing.** **5**: 1-19. **26**: 109-125. **32**: 143-184. **35**: 119-126. **41**: 1-49. **42**: 99-116.
12. **Early Methods of Making Clothing.** **5**: 1-19. **19**: 212-251. **32**: 143-147. **35**: 119-126. **41**: 32-65.
13. **Bleaching and Dyeing.** **7**: 209-212. **8**: 155-156. **8**: 159-163. **10**: 76-78.
14. **Examination of Textile Fibers.** **10**: 128-141. **16**: 127-133. **58**: 151-162.
15. **Clothing in Many Lands.** **31**: 50-104.
16. **The Sewing Machine.** **23**: 114-122. **24**: 79-84. **27**: 333-369. **33**: 84-106. **41**: 75-90.
17. **Clothes Moths and Their Destruction.** **53**: (entire).
18. **Discoverers and Inventors in Science.** (See also page 570.)
    Arkwright, Richard. **18**: 44-47. **24**: 151-154.
    Goodyear, Charles. **27**: 176-218. **33**: 110-134.
    Hargreaves, James. **18**: 41-44. **33**: 38-48.
    Howe, Elias. **24**: 79-84. **27**: 333-369. **33**: 87-106. **41**: 75-90.
    Whitney, Eli. **18**: 53-57. **24**: 61-69. **25**: 219-236. **26**: 96-110. **27**: 75-104. **33**: 63-79. **41**: 1-31.

UNIT VII: PROTECTING OURSELVES FROM DISEASE

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries.

American Medical Association Publications:

2. Miscellaneous Nostrums
3. Nostrums and Quackery, Vol. I.
4. Nostrums and Quackery, Vol. II.
5. The Great American Fraud
6. Caldwell, O. W. and Slosson, E. E. Science Remaking the World
7. Chapin, H. D. Health First, the Fine Art of Living
8. Conn, H. W. Bacteria, Yeasts, and Molds in the Home
9. Doane, R. W. Insects and Disease
10. Darrow, F. L. Masters of Science and Invention
11. Fisher, I. and Lusk, E. L. Healthy Living
12. Haskin, F. J. The Panama Canal
13. Haskin, F. J. The American Government
14. Howard, L. O. The House Fly—Disease Carrier
15. Howard, L. O. Mosquitoes
16. Howe, F. C. The Modern City and Its Problems
17. Hutchinson, W. Preventable Diseases
18. Kelly, H. A. Walter Reed and Yellow Fever
19. Lipman, J. G. Bacteria in Relation to Country Life
20. O'Shea, M. V. and Kellogg, J. H. Making the Most of Life
21. Prudden, T. M. The Story of the Bacteria
22. Reid, W. and Others. Careers for the Coming Men
23. Vallery—Radot, R. The Life of Pasteur
24. Williams, H. S. Tribute from the Animal World

(*B*) Pamphlets and Bulletins

Farmers' Bulletins:

25. No. 444. "Remedies and Preventives Against Mosquitoes." 5¢.
26. No. 450. "Some Facts about Malaria." 5¢.
27. No. 459. "House Flies." 5¢.
28. No. 478. "How to Prevent Typhoid Fever." 5¢.
29. No. 490. "Bacteria and Milk." 5¢.
30. No. 547. "The Yellow Fever Mosquito." 5¢.
31. No. 602. "Production of Clean Milk." 5¢.
32. No. 734. "Fly Traps and Their Operation." 5¢.
33. No. 897. "Fleas and Their Control." 5¢.

34. No. 926. "Some Common Disinfectants." 5¢.
35. No. 1019. "Straining Milk." 5¢.
36. No. 1302. "How to Get Rid of Rats." 5¢
37. No. 1342. "Dairy-Barn Construction."
38. No. 1354. "The Yellow Fever Mosquito." 5¢.
39. No. 1393. "Principles of Dairy-Barn Ventilation." 5¢.
40. No. 1408. "The House Fly and How to Suppress It." 5¢.
41. No. 14. "Migratory Habit of House-Fly Larvae as Indicating Favorable Remedial Measures." 5¢.
42. No. 118. "Experiments in the Destruction of Fly Larvae in Horse Manure." 10¢.
43. No. 342. "Present Status of Pasteurization of Milk." 5¢.
44. No. 973. "Milk Plant Operation." 5¢.

Public Health Service—Keep Well Series:

45. No. 4. "Diphtheria." 5¢.
46. No. 7. "Vaccination." 5¢.
47. No. 1. "Measles." 5¢.
48. No. 11. "What the Farmer Can Do to Prevent Malaria." 5¢.
49. No. 14. "Diphtheria." 5¢.
50. No. 18. "Malaria." 10¢.

Public Health Service Supplements:

51. No. 30. "Common Colds." 5¢.
52. No. 34. "Spanish Influenza—the "Flu." 5¢.
53. No. 29. "Transmission of Disease by Flies." 5¢.

Public Health Service Reprints:

54. No. 9. "Prevention of the Spread of Scarlet Fever." 5¢.
55. No. 28. "Prevention and Destruction of Mosquitoes." 5¢.
56. No. 49. "The Present Organization and Work for the Protection of the United States' Health."
57. No. 61. "Small Pox in the United States." 5¢.
58. No. 74. "The Transmission of Typhus Fever." 5¢.
59. No. 100. "Whooping Cough." 5¢.
60. No. 119. "The Rat." 5¢.
61. No. 260. "Control of Malaria." 5¢.
62. No. 435. "Vaccination against Smallpox."
63. No. 661. "Evolution and Organization of the Public Health Service."
64. Public Health Service Bulletin of the Hygienic Laboratory No. 65. "Facts and Problems of Rabies." 25¢.

Public Health Service Public Health Bulletins:

65. No. 29. "Typhoid Fever." 5¢.
66. No. 65. "Typhoid Fever in Rockville, Maryland." 5¢.

67. Animal Industry Circular No. 190. "Vaccination of Cattle against Tuberculosis." 5¢.

68. Bureau of Standards Circular No. 70. "Materials for the Household." 25¢.

2. GUIDE TO REFERENCES

(*A*) General

7: 139-151. **20:** 218-250. **17:** (entire).

(*B*) Specific Topics

1. **Germs, Harmful and Helpful.** **1:** 30-41. **8:** 1-11. **8:** 100-138. **8:** 203-208. **8:** 214-218. **8:** 235-240. **9:** 1-25. **10:** 186-197. **21:** 14-69. **19:** 13-25.
2. **Carriers of Disease.** **8:** 208-211. **9:** (entire). **14:** 100-174. **19:** 45-160. **19:** 397-401. **21:** 179-215. **58:** (entire). **66:** (entire).
3. **Preventing the Spread of Disease.** **8:** 255-264. **53:** (entire).
4. **Vaccination and Inoculation against Disease.** **8:** 248-254. **10:** 125-127. **24:** 38-43. **46:** (entire). **62:** (entire). **67:** (entire).
5. **Immunity, Active and Passive.** **21:** 141-174.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **The Fly and Its Relation to Disease.** **9:** 57-75. **14:** (entire). **21:** 211-212. **27:** (entire). **53:** (entire).
2. **Mosquitoes and Diseases Carried by Them.** **9:** 76-141. **15:** (entire). **18:** (entire).
3. **Uncommon Diseases Spread by Insects.** **9:** 161-174.
4. **Anti-Fly Measures.** **14:** 175-217. **32:** (entire). **40:** (entire). **41:** (entire). **42:** (entire).
5. **Ticks and Mites Which Spread Disease.** **9:** 26-39.
6. **Destroying Mosquitoes.** **25:** (entire). **48:** (entire). **55:** (entire). **61:** (entire).
7. **Rats, Fleas, and the Plague.** **9:** 142-160. **33:** (entire). **36:** (entire). **60:** (entire).
8. **Pasteurization of Milk.** **8:** 182-196. **43:** (entire). **44:** (entire).
9. **The Work of Health Departments.** **13:** 97-104. **34:** (entire). **56:** (entire). **63:** (entire). **66:** (entire).
10. **Disinfectants.** **6:** 150-160. **68:** 199-202.
11. **The Relation of Air to Disease.** **8:** 230-234. **19:** 45-55. **21:** 199-210.

12. **The Relation of Water and Ice to Disease.** **8:** 222-226. **19:** 56-60. **21:** 184-198. **66:** (entire).
13. **The Relation of Milk and Other Foods to Disease.** **8:** 182-196. **8:** 227-230. **8:** 234-235. **19:** 357-377. **19:** 397-401. **21:** 179-183. **29:** (entire). **31:** (entire). **35:** (entire). **37:** (entire). **39:** (entire).
14. **The Fight against Yellow Fever and Malaria in Cuba and the Panama Canal Zone.** **9:** 120-141. **12:** 105-117. **18:** (entire).
15. **Patent Medicines and Quack Doctors.** **2:** (entire). **3:** (entire). **4:** (entire). **5:** (entire).
16. **Medicine as a Career.** **22:** 61-72.
17. **Communicable Diseases.**
    Infantile Paralysis. **7:** 164-169.
    Diphtheria. **7:** 163-164. **21:** 125-140. **45:** (entire). **49:** (entire).
    Scarlet Fever. **7:** 160-162. **54:** (entire).
    Colds, Pneumonia, and Influenza. **7:** 151-155. **11:** 272-280. **21:** 115-124. **51:** (entire). **52:** (entire).
    Measles. **7:** 159-160. **47:** (entire).
    Whooping Cough. **7:** 155-156. **59:** (entire).
    Malarial Fever. **20:** (entire). **50:** (entire).
    Tuberculosis. **7:** 156-159. **21:** 83-99.
    Typhoid Fever. **21:** 100-108. **28:** (entire). **65:** (entire).
    Smallpox. **7:** 162. **57:** (entire).
    Typhus Fever. **21:** 109-114. **58:** (entire).
    Hydrophobia. **64:** (entire).
    Yellow Fever. **30:** (entire). **38:** (entire).
18. **Discoverers and Inventors in Science.** (See also page 570.)
    Carrol, James. **18:** 272-281.
    Jenner, Edward. **10:** 125-127.
    Lazear, Jesse. **18:** 281-288.
    Morton, William. **10:** 127-130.
    Pasteur, Louis. **1:** 30-34. **6:** 133-149. **10:** 186-197. **23:** (entire). **24:** 38-43.
    Reed, Walter. **18:** (entire).

UNIT VIII: THE NATURE AND CONTROL OF FIRE

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries
2. Caldwell, O. W. and Slosson, E. E. Science Remaking the World
3. Carpenter, F. G. How the World Is Housed

4. Clarke, C. R. The Boys' Book of Chemistry
5. Collins, A. F. Wonders of Chemistry
6. Cooke, A. O. A Visit to a Coal Mine
7. Corbin, T. The Romance of War Inventions
8. Crump, I. The Boys' Book of Firemen
9. Crump, I. The Boys' Book of Forest Rangers
10. Darrow, F. L. The Boys' Own Book of Great Inventions
11. Darrow, F. L. The Boys' Own Book of Science
12. Elliott, G. F. S. The Romance of Savage Life
13. Fabre, J. H. The Wonder Book of Chemistry
14. Faraday, M. Chemical History of a Candle
15. Fisher, E. E. Resources and Industries of the United States
16. Forman, S. E. Stories of Useful Inventions
17. Gibson, C. R. The Romance of Modern Manufacture
18. Gibson, C. R. Chemistry and Its Mysteries
19. Gibson, C. R. Heroes of Science
20. Hill, C. T. Fighting a Fire
21. Holland, R. S. Historic Inventions
22. Husband, J. A Year in a Coal Mine
23. Iles, G. Flame, Electricity, and the Camera
24. Jameson, H. L. The Flame Fiend
25. Jenks, T. The Fireman
26. Kenlon, J. Fire and Fire-Fighters
27. Knox, G. D. All about Engineering
28. Moffett, C. Careers of Danger and Daring
29. Morris, C. Home Life in All Lands, Vol. I.
30. Mowry, W. A. and A. M. American Inventions and Inventors
31. Pack, N. N. Our Vanishing Forests
32. Pack, C. L. School Book of Forestry
33. Philip, J. C. The Romance of Modern Chemistry
34. Philip, J. C. Achievements of Chemical Science
35. Pinchot, G. A. A Primer of Forestry, Part I.
36. Rocheleau, W. F. Great American Industries, Vol. I.
37. Rogers, J. E. Earth and Sky Every Child Should Know
38. Roth, F. First Book of Forestry
39. Seeley, H. G. The Story of the Earth
40. Seton, E. T. and Baden-Powell, Sir Robt. Boy Scouts of America: Official Handbook
41. Tappan, E. M. Diggers in the Earth
42. Tappan, E. M. Makers of Many Things
43. Tower, W. S. The Story of Oil
44. Washburne, C. W. and H. C. The Story of the Earth
45. White, M. The Fuels of the Household

46. Williams, H. S. Tribute from the Mineral World
47. Williams, A. How It Is Made
48. Williams, A. How It Works
49. Williams, A. The Romance of Modern Engineering
50. Williams, A. The Romance of Mining
51. Yates, R. F. The Boys' Play Book of Chemistry

(*B*) Pamphlets and Bulletins

Farmers' Bulletins:
52. No. 904. "Fire Prevention and Fire Fighting on the Farm." 5¢.
53. No. 1023. "Machinery for Cutting Fire Wood." 5¢.
54. Forest Service Bulletin No. 117. "Forest Fires." 10¢.
Department of Agriculture Miscellaneous Circulars:
55. No. 7. Forest Fire Prevention Handbook for School Children of Calif." 10¢.
56. No. 19. "Forest Fires in Inter-Mountain Regions." 5¢.
57. Bureau of Mines Bulletin No. 16. "The Uses of Peat for Fuel and Other Purposes."
Bureau of Mines Technical Papers:
58. No. 97. "Saving Fuel in Heating a House." 5¢.
59. No. 199. "Five Ways of Saving Fuel in Heating Houses." 5¢.
60. Agriculture Bulletin No. 753. "Use of Wood for Fuel." 10¢.
Bureau of Standards Circulars:
61. No. 55. "Measurements for the Household." 25¢.
62. No. 70. "Materials for the Household." 25¢.
63. No. 75. "Safety for the Household." 25¢.
The Mentor:
64. "The Story of Coal." 25¢.
65. "The Story of Oil." 25¢.

2. GUIDE TO REFERENCES

(*A*) General

5: 30-44. **16**: 13-27. **23**: (entire). **30**: 11-50. **33**: 50-60. **33**: 118-130. **33**: 154-160. **45**: 10-25.

(*B*) Specific Topics

1. **Combustion.** **13**: 83-95. **13**: 211-223. **14**: (entire). **18**: 122-142. **34**: 36-50. **62**: 204-207.
2. **Our Common Fuels.** **2**: 12-46. **31**: 36-41. **33**: 131-153. **34**: 50-80. **41**: 1-10. **45**: 26-72. **53**: (entire). **60**: (entire). **62**: 209-213.

3. **Conservation of Fuels.** **1:** 97-103. **45:** 81-92. **58:** (entire). **59:** (entire).
4. **Composition of Air.** **4:** 55-68. **5:** 1-14. **11:** 59-70.
5. **Principal Causes of Fires.** **63:** 91-104.
6. **Fire Prevention.** **24:** (entire). **52:** (entire). **63:** 54-108.
7. **Fire Extinguishers.** **63:** 87-91.
8. **Molecules.** **33:** 28-38. **51:** 3-17.
9. **Uses of Fuels.** **34:** 50-80.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Preparing and Experimenting with Oxygen.** **4:** 42-43. **11:** 38-48. **11:** 179-190. **13:** 96-108. **13:** 124-151. **13:** 187-210. **13:** 224-229. **18:** 40-49. **51:** 39-48.
2. **Superstitions and Early Theories of Fire.** **3:** 257-270. **12:** 154-162 **34:** 1-14. **34:** 32-36.
3. **Fighting Fires.** **8:** (entire). **20:** (entire). **25:** (entire). **26:** (entire) **28:** 209-254.
4. **Forest Fires.** **9:** (entire). **31:** 99-109. **32:** 53-63. **35:** 77-88. **38:** 104-115. **54:** (entire). **55:** (entire). **56:** (entire).
5. **Methods of Making Fire.** **12:** 154-162. **17:** 221-228. **23:** 18-23. **29:** 207-210. **33:** 118-130. **40:** 79-88.
6. **How Candles Are Made.** **30:** 67-72. **47:** 72-89.
7. **How Matches Are Made.** **3:** 314-316. **11:** 199. **16:** 3-12. **34:** 92-97. **42:** 1-5. **47:** 46-60
8. **Davy Safety Lamp.** **21:** 126-139. **46:** 6-11.
9. **Explosives.** **4:** 219-231. **5:** 85-98. **7:** 27-38. **10:** 327-335. **33:** 166-179.
10. **Early Ideas of Chemistry.** **4:** 3-12. **18:** 24-32.
11. **Experiments with Carbon Dioxide.** **51:** 54-60.
12. **How Coal Was Formed.** **15:** 143-145. **30:** 37-51. **36:** 7-44. **41:** 1-10. **64:** (entire).
13. **Mining Coal.** **6:** 1-88. **15:** 146-151. **22:** (entire). **27:** 152-159. **34:** 80-93. **41:** 1-10. **50:** 274-319. **64:** (entire).
14. **Digging for Oil.** **3:** 281-290. **27:** 162-166. **36:** 45-59. **43:** (entire). **49:** 349-366. **65:** (entire).
15. **Petroleum Fuels.** **2:** 12-46. **15:** 156-165. **30:** 77-80. **41:** 84-94. **62:** 224.
16. **Natural Gas.** **36:** 60-74.
17. **Gas Meter.** **61:** 91-102.

18. **Manufacture of Artificial Gas.** **3**: 291-299. **30**: 81-84. **34**: 68-85. **45**: 73-77. **48**: 394-399. **62**: 225-227.
19. **Peat.** **34**: 57-60. **57**: (entire).
20. **The Preparation of Hydrogen.** **18**: 33-40. **51**: 48-53.
21. **Making Fireworks at Home.** **11**: 202-213. **51**: 162-172.
22. **Making a Chemistry Laboratory at Home.** **4**: 13-31. **51**: 18-38.
23. **Elements and Compounds.** **13**: 6-26. **13**: 42-69. **18**: 50-103. **78**: 234-238.
24. **Discoverers and Inventors in Science.** (See also page 570.)
    Davy, Sir Humphrey. **21**: 126-139. **46**: 6-11.
    Lavoisier, Antoine. **34**: 32-36.
    Priestley, Joseph. **19**: 164-178. **34**:1-14.

UNIT IX: PROVIDING HEAT AND FRESH AIR IN OUR BUILDINGS

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries
2. Allen, J. K. Sanitation in the Modern Home
3. Brechner, C. H. Household Physics
4. Carpenter, F. G. How the World Is Housed
5. Collins, A. F. The Amateur Mechanic
6. Earle, A. M. Home Life in Colonial Days
7. Elliott, G. F. S. The Romance of Savage Life
8. Williams, A. Thinking It Out

(*B*) Pamphlets and Bulletins

Farmers' Bulletins:

9. No. 771. "Homemade Fireless Cookers and Their Use." 5¢.
10. No. 1174. "One Register Furnaces." 5¢.
11. No. 1230. "Chimneys and Fire Places—How to Build Them." 5¢.

United States Fuel Administration:

12. No. 7. "How to Burn Soft Coal in Base-Burner Stoves."
13. No. 23. "Lessons in Coal Saving."

Bureau of Mines Technical Papers:

14. No. 97. "Saving Fuel in Heating a House." 5¢.
15. No. 199. "Five Ways of Saving Fuel in Heating Houses." 5¢.
16. No. 208. "How to Improve the Hot-Air Furnace." 5¢.
17. Taylor Instrument Companies Pamphlet. "Humidity, Its Effect on Our Health and Comfort." 10¢.

Bureau of Standards Circulars:

18. No. 55. "Measurements for the Household." 25¢.
19. No. 70. "Materials for the Household." 25¢.

2. GUIDE TO REFERENCES

(*A*) General

4: 271-278. **19:** 214-216.

(*B*) Specific Topics

(But few references on Specific Topics are given. These topics may be found in any physics textbook.)

1. **Fireplaces.** **6:** 52-75. **8:** 280-281. **11:** (entire).
2. **Stoves.** **12:** (entire).
3. **Hot-Air Furnaces.** **2:** 128-143. **5:** 67-68. **10:** (entire). **16:** (entire).
4. **Hot-Air System of Heating.** **2:** 114-127. **5:** 69-70. **8:** 282-285.
5. **Steam Heating Systems.** **2:** 96-113. **5:** 70-73.
6. **Methods of Heat Transfer.** **3:** 41-59. **8:** 268-276.
7. **Ventilation.** **2:** 144-160. **17:** (entire). **18:** 108-119.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Fireless Cookers and How to Make Them.** **1:** 120. **8:** 276-277. **9:** (entire).
2. **Vacuum Bottles.** **8:** 277-278.
3. **Saving Fuel in Heating Devices.** **1:** 97-103. **12:** (entire). **13:** (entire). **14:** (entire). **15:** (entire).
4. **Construction and Operation of Hot-Air Furnaces.** (Write to manufacturers of these devices. You can learn their addresses by examining furnaces, asking the hardware man, or by looking up their advertisements in newspapers and magazines.)
5. **Construction and Operation of Hot-Water Heating Systems.** (Follow suggestions given under Topic 4).
6. **Construction and Operation of Steam Heating Systems.** (Follow suggestions given under Topic 4).
7. **Construction and Operation of Ventilating Systems.** (Follow suggestions given under Topic 4). **2:** 144-168.
8. **Construction and Operation of Oil Heaters.** (Follow suggestions given under Topic 4).
9. **Construction of Radiators and Air Vents.** (Follow suggestions given under Topic 4).
10. **Asbestos and Other Insulating Materials for Heating Devices.** (Follow suggestions given under Topic 4.)

UNIT X: MATERIALS FOR CONSTRUCTION

1. REFERENCES

(*A*) Books

1. Allen, J. K. Sanitation in the Modern Home
2. Baker, R. S. The Boy's Book of Inventions
3. Bassett, S. W. The Story of Glass
4. Bassett, S. W. The Story of Lumber
5. Bond, A. R. The American Boys' Engineering Book
6. Bond, A. R. The Scientific American Boy
7. Brown, E. A. Rubber
8. Burns, E. E. The Story of Great Inventions
9. Carpenter, F. G. How the World Is Housed
10. Clarke, C. R. The Boys' Book of Chemistry
11. Clodd, E. The Story of "Primitive" Man
12. Collins, A. F. Wonders of Chemistry
13. Collins, A. F. The Amateur Mechanic
14. Cooke, A. O. A Day in an Iron Works
15. Corbin, T. The Romance of War Inventions
16. Darrow, E. L. The Boys' Own Book of Great Inventions
17. Darrow, F. L. The Boys' Own Book of Science
18. Earle, A. M. Home Life in Colonial Days
19. Elliott, G. F. S. The Romance of Savage Life
20. Fabre, J. H. The Story Book of Science
21. Fabre, J. H. The Wonder Book of Chemistry
22. Fisher, E. E. Resources and Industries of the United States
23. Forman, S. E. Stories of Useful Inventions
24. Gibson, C. R. The Romance of Modern Manufacture
25. Gibson, C. R. Chemistry and Its Mysteries
26. Hale, E. E. Stories of Invention
27. Hall, A. N. Handicraft for Handy Boys
28. Holland, R. S. Historic Inventions
29. Iles, G. Flame, Electricity, and the Camera
30. Knox, G. D. All about Engineering
31. Maddox, H. A. Paper
32. Mills, E. A. The Story of a Thousand-Year Pine
33. Mills, J. C. Searchlights on Some American Industries
34. Moffett, C. Careers of Danger and Daring
35. Morris, C. Home Life in All Lands, Vol. I.
36. Morris, C. Home Life in All Lands, Vol. II.
37. Pack, C. L. The School Book of Forestry
38. Pack, A. N. Our Vanishing Forests

39. Parkman, M. R. Conquests of Invention
40. Philip, J. C. The Romance of Modern Chemistry
41. Philip, J. C. Achievements of Chemical Science
42. Pinchot, G. A Primer of Forestry, Part I.
43. Pinchot, G. The Training of a Forester
44. Reid, W. and Others. Careers for the Coming Men
45. Reynolds, C. J. How Man Conquered Nature
46. Rocheleau, W. F. Great American Industries, Vol. I.
47. Rocheleau, W. F. Great American Industries, Vol. II.
48. Rocheleau, W. F. Great American Industries, Vol. III.
49. Rogers, J. E. Earth and Sky Every Child Should Know
50. Rolt-Wheeler, F. The Boy with the U. S. Foresters
51. Roth, F. First Book of Forestry
52. Seers, A. W. The Earth and Its Life
53. Seton, E. T. and Baden-Powell, Sir Robert, Boy Scouts of America: Official Handbook
54. Smith, J. R. The Story of Iron and Steel
55. Tappan, E. M. The Farmer and His Friends
56. Tappan, E. M. Diggers in the Earth
57. Tappan, E. M. Makers of Many Things
58. Wheelwright, W. B. Essential Facts about Paper
59. Williams, H. S. Science and the Mechanical Arts
60. Williams, H. S. Science and Industry
61. Williams, H. S. Tribute from the Mineral World
62. Williams, A. How It Is Made
63. Williams, A. The Romance of Mining
64. Williams, A. Thinking It Out

(*B*) Pamphlets and Booklets

Farmers' Bulletins:

65. No. 173. "Primer of Forestry." 5¢.
66. No. 235. "Cement, Mortar, and Concrete." 5¢.
67. No. 358. "Primer of Forestry." 5¢.
68. No. 744. "Preservative Treatment of Farm Timbers." 5¢.
69. No. 1071. "Making Woodlands Profitable." 5¢.
70. No. 1210. "Measuring and Marketing Farm Timber." 5¢.
71. No. 1219. "Floors and Floor Coverings." 5¢.
72. No. 1392. "Black Walnut for Timber and Nuts." 5¢.
73. No. 1452. "Painting on the Farm." 5¢.
74. No. 12. "Uses of Commercial Woods of the U. S." 10¢.
75. No. 364. "Forest Conservation for States in Southern Pine Regions." 5¢.

76. No. 506. "Production of Lumber." 5¢.
77. No. 552. "Seasoning of Wood." 5¢.
78. No. 605. "Lumber Used in the Manufacture of Wooden Products." 5¢.
79. No. 718. "Small Saw Mills." 10¢.

DEPARTMENT OF AGRICULTURE CIRCULARS:

80. No. 140. "Lumber Expert in Our Forests." 5¢.
81. No. 211. "Government Forest Work." 5¢.
82. AGRICULTURAL DEPARTMENT REPORT NO. 117. "Substitution of Other Materials for Wood." 15¢.
83. FOREST SERVICE BULLETIN NO. 84. "Preservative Treatment of Poles." 15¢.
84. CENSUS BUREAU REPORT (1920). "Stone Quarrying Industries." 5c.
85. BUREAU OF STANDARDS CIRCULAR NO. 70. "Materials for the Household." 25¢.

THE MENTOR:

86. "The Story of Iron and Steel." 25¢.
87. "Glass and Glass Making." 25¢.
88. "The Story of Paper." 25¢.

2. GUIDE TO REFERENCES

(*A*) GENERAL

9: (entire). **45**: 126-147.

(*B*) SPECIFIC TOPICS

1. **Lumber as a Building Material.** **1**: 31-63. **4**: (entire). **9**: 64-90. **13**: 26-33. **20**: 37-45. **22**: 119-134. **32**: (entire). **33**: 1-32. **37**: 11-30. **37**: 41-52. **38**: 1-36. **42**: 7-24. **47**: 7-50. **51**: 133-179. **51**: 217. **55**: 98-106. **69**: (entire). **70**: (entire). **71**: (entire). **72**: (entire). **74**: (entire). **76**: (entire). **77**: (entire). **78**: (entire). **79**: (entire). **80**: (entire). **85**: 28-63.
2. **The Principal Building Stones.** **9**: 110-122. **13**: 123-141. **22**: 136-139. **46**: 113-162. **56**: 11-20. **63**: 338-358. **84**: (entire).
3. **Clay and Clay Products.** **9**: 127-142. **13**: 33-36. **36**: 227-238. **56**: 31-38. **85**: 14-27.
4. **Cement and Concrete.** **9**: 122-126. **13**: 40-45. **56**: 21-30. **61**: 66-85. **66**: (entire). **85**: 86-105.
5. **Lime, Mortar, and Plaster.** **13**: 38-40. **40**: 91-94. **41**: 102-105. **85**: 76-86. **85**: 106-114.
6. **The Manufacture of Glass.** **3**: (entire). **9**: 188-204. **48**: 37-74. **61**: 135-152. **62**: 117-131. **87**: (entire).

7. **Iron and Steel.** **9**: 142-172. **12**: 64-72. **14**: (entire). **22**: 170-178. **24**: 274-284. **52**: 157-167. **54**: (entire). **56**: 56-64. **61**: 29-55. **85**: 63-66. **86**: (entire).
8. **Other Metals.** **9**: 173-180. **20**: 49-63.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Forestry and Great Forests.** **37**: 79-94. **37**: 109-159. **38**: 90-189. **42**: 25-43. **50**: (entire). **51**: (entire). **65**: (entire). **67**: (entire). **75**: (entire). **81**: (entire).
2. **The Stone Age.** **45**: 126-147. **52**: 116-137. **61**: (entire).
3. **The Bronze Age.** **11**: (entire). **45**: 126-147. **52**: 147-156.
4. **History of Iron and Steel.** **8**: 242. **26**: 259-293. **52**: 157-167. **54**: 12-72.
5. **Skyscrapers.** **2**: 283-319. **34**: 1-39. **60**: 113-128.
6. **Early Methods of Mining.** **63**: 17-44.
7. **Early Homes.** **18**: 1-31. **19**: 252-265. **23**: 147-167. **35**: 136-187.
8. **How to Build a Log Cabin and Other Small Houses.** **6**: 124-137. **6**: 171-182. **53**: 122-12.
9. **Formation of Rocks.** **49**: 27-71. **49**: 147-151.
10. **Alloys.** **10**: 117-120. **16**: 365-366. **17**: 164-176.
11. **Homes in Foreign Lands.** **9**: 9-64.
12. **Manufacture of Paper.** **9**: 204-221. **12**: 141-143. **20**: 77-79. **21**: 371-374. **31**: 1-14. **38**: 42-58. **48**: 141-159. **57**: 25-35. **58**: (entire). **59**: 64-88. **85**: 163-173. **88**: (entire).
13. **The Manufacture of Copper.** **12**: 59-64. **56**: 65-75.
14. **The Manufacture of Aluminum.** **56**: 76-83.
15. **The Manufacture of Rubber.** **7**: (entire). **33**: 131-164. **57**: 6-15. **85**: 140-145.
16. **Manufacture of Metals.** **10**: 103-117. **15**: 97-107. **23**: 39-53. **29**: 35-48. **40**: 61-71. **46**: 75-112. **49**: 167-174. **62**: 207-241.
17. **Preservation of Building Materials.** **9**: 221-231. **12**: 144-156. **68**: (entire). **73**: (entire). **83**: (entire). **85**: 114-129.
18. **Chinaware, Porcelain, and Pottery Manufacture.** **24**: 176-194. **28**: 42-52. **57**: 56-63. **61**: 86-134. **62**: 96-116.
19. **Mining Metals.** **30**: 159-161. **61**: 1-28. **63**: 44-131. **63**: 154-196. **63**: 211-245. **63**: 258-273. **63**: 320-337.
20. **The Development of the Forge.** **5**: 59-69. **23**: 39-53.
21. **Home Construction Projects with Wood and Brass.** **27**: (entire).

22. **Unusual Metals.** **25:** 171-183.

23. **Mechanical Engineering as a Profession.** **44:** 107-117.

24. **Forestry as a Profession.** **43:** (entire).

25. **Discoverers and Inventors in Science.** (See also page 570.)
Bessemer, Sir Henry. **26:** 259-293. **61:** 49-51.
Goodyear, Charles. **39:** 110-134.
Kelley, William. **39:** 298-309.

UNIT XI: MACHINES FOR DOING WORK

1. REFERENCES

(*A*) Books

1. Barnard, C. The Tools and Machines
2. Bond, A. R. The American Boys' Engineering Book
3. Bond, A. R. With the Men Who Do Things
4. Burns, E. E. The Story of Great Inventions
5. Collins, A. F. The Amateur Mechanic
6. Darrow, F. L. The Boys' Own Book of Great Inventions
7. Decker, W. F. The Story of the Engine
8. Forman, S. E. Stories of Useful Inventions
9. Holland, R. S. Historic Inventions
10. Iles, G. Leading American Inventors
11. Morris, C. Home Life in All Lands, Vol. I.
12. Mowry, W. A. and A. M. American Inventions and Inventors
13. Parkman, M. R. Conquests of Invention
14. Quennell, M. and C. H. B. Everyday Life in the New Stone, Bronze, and Early Iron Ages
15. Reynolds, M. J. How Man Conquered Nature
16. Sanford, A. H. The Story of Agriculture in the United States
17. Seers, A. W. The Earth and Its Life
18. Williams, A. How It Works
19. Williams, A. Thinking It Out

(*B*) Bulletins and Pamphlets

Farmers' Bulletins:

20. No. 927. "Farm Home Conveniences." 5¢.
21. No. 2. "International Metric System on Weights and Measures." 5¢.
22. Bureau of Standards Reprint No. 17. "History of Standard Weights and Measures of the United States." 10¢.
23. Bureau of Education Lessons in Community and National Life, Lesson A-8. "The Rise of the Machine Industry."

24. Bureau of Standards Circular No. 55. "Measurements for the Household." 25¢.

25. Bureau of Standards Circular No. 70. "Materials for the Household." 25¢.

2. GUIDE TO REFERENCES

(A) General

1: (entire).

(B) Specific Topics

1. **Work and Simple Machines.** **5:** 75-156. **19:** 75-121. **20:** (entire). **24:** 12-32.
2. **Units of Work, Power, and Energy.** **19:** 49-74.
3. **Friction and Its Reduction.** **5:** 87-90. **19:** 75-104. **25:** 229-233.
4. **The Metric System.** **21:** (entire). **22:** (entire).
5. **The Transmission of Power.** **5:** 77-87. **5:** 148-156.
6. **Centrifugal Force and Its Use.** **19:** 125-149.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Primitive Tools and Weapons.** **4:** 237-238. **6:** 232-236. **11:** 269-290. **14:** 3-233. **15:** 1-42. **15:** 148-171. **17:** 116-167.
2. **Farm Machinery.** **6:** 232-239. **9:** 189-205. **12:** 117-131. **16:** 246-265
3. **The Cream Separator.** **18:** 381-385.
4. **The Sewing Machine.** **9:** 206-214.
5. **History of Machines.** **1:** (entire). **4:** 237-238. **14:** 163-233. **15:** 148-171. **23:** (entire).
6. **Building Skyscrapers.** **3:** 9-34. **6:** 232-239.
7. **Development of the Plow.** **8:** 73-84. **16:** 136-143.
8. **Development of the Reaper.** **8:** 85-96. **16:** 144-158.
9. **Discoverers and Inventors in Science** (See also page 570).
   Archimedes. **4:** 1-18.
   Goodyear, Charles. **13:** 110-134.
   Howe, Elias. **9:** 206-214.
   McCormick, Cyrus. **9:** 189-205. **13:** 8-28.

UNIT XII: PUTTING THE FORCES OF AIR AND WATER TO WORK

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries
2. Anderson, F. I. Electricity for the Farm
3. Bond, A. R. The American Boys' Engineering Book
4. Bond, A. R. The Scientific American Boy
5. Bond, A. R. On the Battlefront of Engineering
6. Bond, A. R. With the Men Who Do Things
7. Burns, E. E. The Story of Great Inventions
8. Cochrane, C. H. Wonders of Modern Mechanism
9. Collins, A. F. The Amateur Mechanic
10. Collins, F. A. Sentinels along Our Coast
11. Corbin, T. The Romance of Submarine Engineering
12. Fisher, E. E. Resources and Industries of the United States
13. Fournier, d'Albe, E. E. Wonders of Physical Science
14. Hall, A. N. Homemade Toys for Girls and Boys
15. Lane, M. A. L. Triumphs of Science
16. Lynde, C. J. Home Water Works
17. Moffett, C. Careers of Danger and Daring
18. Parkman, M. R. Conquests of Inventions
19. Tappan, E. M. Travelers and Traveling
20. Williams, H. S. The Conquest of Sea and Land
21. Williams, A. How It Works
22. Williams, A. The Romance of Modern Engineering
23. Williams, A. A Book of the Sea
24. Williams, A. Thinking It Out
25. Williams, A. The Romance of Modern Locomotion

(*B*) Pamphlets and Bulletins

26. United States Geological Survey. "The World Atlas of Commercial Geography, Part II." $1.00.

2. GUIDE TO REFERENCES

(*A*) General

(See encyclopedias, and also textbooks on physics.)

(*B*) Specific Topics

1. **Uses of Air Pressure.** **13**: 80-88. **16**: 147-157.
2. **Compressed Air and Its Uses.** **5**: 288-303. **8**: 158-165. **17**: 40-86. **19**: 44-53.
3. **Harnessing the Force of Wind.** **9**: 94-99.
4. **Water Wheels.** **1**: 77-85. **2**: 56-85. **5**: 92-113. **7**: 165-166. **9**: 99-105. **9**: 110-111. **16**: 231-242. **21**: 375-381. **24**: 203-204.
5. **Hydraulic Presses.** **21**: 361-364. **24**: 200-203.
6. **Water Power.** **2**: 32-41. **12**: 166-169. **26**: (entire).

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Homemade Windmills.** **4**: 273-282. **14**: 1-9.
2. **Home Construction of Water Wheels.** **1**: 77-85 **3**: 237-247. **4**: 240-253. **14**: 38-47.
3. **How to Build a Small Dam.** **3**: 231-237.
4. **Divers and Diving Bells.** **6**: 224-239. **11**: 32-69. **11**: 304-310. **17**: 40-46. **21**: 187-199. **21**: 335-340. **23**: 271-304.
5. **Underground Tunnels and Their Construction.** **5**: 288-324. **6**: 69-97. **11**: 196-225.
6. **The Harnessing of Niagara.** **15**: 120-131. **22**: 11-34.
7. **The Construction of Dams.** **5**: 3-40.
8. **Caissons and Their Uses.** **5**: 304-324. **6**: 34-62. **10**: 47-73.
9. **Railway Air-Brakes.** **20**: 118-126. **21**: 187-199. **25**: 190-199.
10. **Water Power in the United States.** **12**: 166-169. **26**: (entire).
11. **Pneumatic Water Supplies in Houses.** (See references under Unit IV —same title.)
12. **Discoverers and Inventors in Science** (See also page 570.)
    Guericke, Otto von. **7**: 20-25. **13**: 80-88.
    Westinghouse, George. **18**: 275-292. **20**: 118-126.

UNIT XIII: USING STEAM AND EXPLODING GAS FOR POWER

1. REFERENCES

(*A*) Books

1. Baker, R. S. The Boys' Book of Inventions
2. Burns, E. E. The Story of Great Inventions
3. Caldwell, O. W. and Slosson, E. E. Science Remaking the World

4. Cochrane, R. The Romance of Industry and Invention
5. Collins, A. F. Keeping Up with Your Motor Car
6. Collins, A. F. Motor Car Starting and Lighting
7. Collins, A. F. Wonders of Chemistry
8. Collins, A. F. The Amateur Mechanic
9. Corbin, T. Mechanical Inventions of Today
10. Darrow, F. L. The Boys' Own Book of Great Inventions
11. Decker, W. F. The Story of the Engine
12. Doubleday, R. Stories of Inventors
13. Fabre, J. H. The Story Book of Science
14. Forman, S. E. Stories of Useful Inventions
15. Fournier d'Albe, E. E. Wonders of Physical Science
16. Gibson, C. R. Chemistry and Its Mysteries
17. Holland, R. S. Historic Inventions
18. Iles, G. Flame, Electricity, and the Camera
19. Moffett, C. Careers of Danger and Daring
20. Mowry, W. A. and A. M. American Inventions and Inventors
21. Parkman, M. R. Conquests of Invention
22. Rocheleau, W. F. Great American Industries, Vol. III.
23. Tappan, E. M. Travelers and Traveling
24. Thurstone, R. H. Robert Fulton
25. Verrill, A. H. Harper's Gasoline Engine Book
26. Williams, H. S. The Conquest of Sea and Land
27. Williams, A. How It Works
28. Williams, A. The Romance of Modern Inventions
29. Williams, A. Thinking It Out
30. Williams, A. Wonders of Mechanical Ingenuity

(*B*) Pamphlets and Bulletins

31. Farmers' Bulletin No. 1013. "Practical Hints on Running a Gas Engine." 5¢.
32. Conant, J. B. "Chemistry of the Automobile." Macmillan Co. 12¢.
33. Black, H. N. "Physics of the Automobile." Macmillan Co. 12¢.

2. GUIDE TO REFERENCES

(*A*) General

14: 7-36.

(*B*) Specific Topics

1. Generation of Steam for Power. **7:** 24-26. **8:** 112-115. **11:** 36-60. **13:** 216-226. **27:** 14-31. **29:** 285-296.

2. **Construction and Operation of the Steam Engine.** **8:** 122-131. **11:** 61-102. **27:** 44-59.
3. **The Steam Locomotive.** **10:** 206-211. **11:** 102-128.
4. **Construction and Operation of the Gas Engine.** **4:** 12-20. **5:** 61-78. **8:** 135-147. **10:** 212-231. **11:** 178-248. **16:** 103-121. **27:** 87-111. **30:** 112-129. **31:** (entire). **32:** (entire). **33:** (entire).

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **History of the Steam Engine.** **1:** 244. **10:** 194-206. **11:** 21-36. **15:** 88-100. **17:** 70-83. **18:** 48-63. **24:** 1-27. **29:** 223-225.
2. **Development of the Modern Locomotive.** **10:** 206-211. **17:** 140-167. **26:** 98-118.
3. **History of the Gas Engine.** **2:** 150-154. **4:** 192-204. **9:** 296-313. **10:** 212-231. **12:** 67-85. **28:** 224-258.
4. **From Cart to Automobile.** **1:** 119-169. **26:** 128-145.
5. **Safety Devices for the Boiler—Safety Valve, Water Gauge, Steam Gauge, and Speed Governor.** **1:** 35-36. **8:** 119-122. **16:** 116-118. **27:** 31-39. **27:** 67-70.
6. **The Automobile Industry.** **3:** 12-46. **23:** 74-81.
7. **Engineering as a Profession.** **19:** 377-418.
8. **Steam Turbines.** **2:** 163-171. **10:** 205-206. **11:** 128-163. **27:** 74-86.
9. **Hot-Air Engines.** **8:** 132-135.
10. **Compound Steam Engines.** **27:** 59-62.
11. **The Gasoline System of the Automobile.** **5:** 78-94. **25:** 34-46.
12. **Ignition System.** **5:** 94-111.
13. **How the Automobile Is Lubricated.** **5:** 112-126.
14. **How Gas Engines Are Kept Cool.** **5:** 127-137. **25:** 20-34.
15. **Transmitting Power in the Automobile.** **25:** 200-224.
16. **The Lighting and Starting System of an Automobile.** **5:** 138-151. **6:** (entire). **25:** 46-73.
17. **Discoverers and Inventors in Science.** (See also page 570.)
    Newcomen, Thomas. **2:** 36-38. **10:** 194-206.
    Papin, Denis. **2:** 34-35. **15:** 88-100.
    Stephenson, George. **2:** 155-163. **17:** 140-167. **26:** 98-118.
    Watt, James. **2:** 38-42. **10:** 194-206. **17:** 70-83. **21:** 19-216.

UNIT XIV: GENERATING AND USING ELECTRICITY

1. REFERENCES

(*A*) Books

1. Adams, J. H. Harper's Electricity Book for Boys
2. Anderson, F. I. Electricity for the Farm
3. Baker, R. S. The Boys' Second Book of Inventions
4. Burns, E. E. The Story of Great Inventions
5. Clarke, C. R. The Boys' Book of Chemistry
6. Collins, A. F. Wonders of Chemistry
7. Collins, A. F. The Amateur Mechanic
8. Darrow, F. L. The Boys' Own Book of Great Inventions
9. Darrow, F. L. The Boys' Own Book of Science
10. Fabre, J. H. The Story Book of Science
11. Fournier, d'Albe, E. E. Wonders of Physical Science
12. Gibson, C. R. Chemistry and Its Mysteries
13. Gibson, C. R. Heroes of Science
14. Hall, A. N. Homemade Toys for Girls and Boys
15. Houston, E. J. The Wonder Book of Magnetism
16. Iles, G. Flame, Electricity, and the Camera
17. Johnson, V. E. Electricity and Electrical Magic
18. Knox, G. D. All about Engineering
19. Koester, F. Electricity for the Farm and Home
20. Meadowcroft, W. H. The Boy's Life of Edison
21. Morgan, A. P. The Boy Electrician
22. Philip, J. C. The Romance of Modern Chemistry
23. Reetz, H. C. Electroplating
24. Reid, W. and Others. Careers for the Coming Men
25. Slosson, E. E. Creative Chemistry
26. St. John, T. M. The Study of the Electric Motor by Experiment
27. St. John, T. M. Real Electric Toy Making for Boys
28. Tappan, E. M. Travelers and Traveling
29. Williams, H. S. The Conquest of Sea and Land
30. Williams, A. How It Works
31. Williams, A. How It Is Made
32. Williams, A. The Romance of Modern Engineering
33. Willoughby, G. A. Practical Electricity for Beginners
34. Woodhull, J. F. Electricity and Its Everyday Uses
35. Wright, H. C. Children's Stories of the Great Scientists
36. Yates, R. F. The Boys' Play Book of Chemistry

(*B*) Pamphlets and Bulletins

37. Farmers' Bulletin No. 1430. "Power for the Farm from Small Streams." 5¢.
38. U. S. Signal Office Training Pamphlet No. 7. "Primary Batteries." 10¢.

Bureau of Standards Circulars:

39. No. 75. "Safety for the Household." 25¢.
40. No. 92. "Operation and Care of Vehicle-Type Batteries." 25¢.
41. No. 55. "Measurements for the Household." 25¢.

2. GUIDE TO REFERENCES

Specific Topics

1. **Primary Electric Cells.** **1:** 12-32. **4:** 88-96. **5:** 167-172. **6:** 173-180. **8:** 251-256. **16:** 135-152. **21:** 53-81. **22:** 290-301. **23:** 15-20. **34:** 248-262. **38:** (entire).
2. **Measurement of Electricity.** **2:** 98-108. **7:** 166-168. **21:** 92-99. **33:** 28-32. **33:** 82-92. **41:** 82-90.
3. **Storage Cells and Batteries.** **1:** 21-29. **1:** 229-249. **5:** 172-173. **6:** 180-183. **7:** 175-177. **8:** 272-276. **9:** 230-234. **20:** 274-282. **33:** 22-25.
4. **Magnetism and Electromagnetism.** **1:** 54-59. **8:** 1-15. **15:** (entire). **17:** 13-43. **21:** 82-91. **30:** 115-118.
5. **The Construction and Operation of Dynamos.** **1:** 229-241. **2:** 89-120. **4:** 96-110. **7:** 169-173. **8:** 276-296. **11:** 159-169. **21:** 301-317. **30:** 159-177. **33:** 25-26. **34:** 3-25.
6. **The Construction and Operation of Motors.** **7:** 173-174. **8:** 284-289. **17:** 44-53. **21:** 289-300. **26:** (entire). **27:** 75-81. **27:** 97-114. **30:** 177-179. **34:** 43-56.
7. **Electroplating.** **5:** 178-185. **6:** 183-187. **9:** 224-228. **23:** (entire). **30:** 185-186. **31:** 458-460. **36:** 153-154.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Home Construction of Cells.** **1:** 12-32. **27:** 31-34.
2. **History of Electricity.** **1:** 238-240. **4:** 43-86. **8:** 246-251. **8:** 276-280. **11:** 100-123. **11:** 159-169. **16:** 94-109.
3. **Static Electricity.** **1:** 312-326. **8:** 244-251. **10:** 150-191. **11:** 100-113. **17:** 76-102. **21:** 16-52. **27:** 13-25.

4. **Electric Furnaces and Heaters.** **1:** 340-343. **3:** 113-152. **6:** 225-239. **8:** 258-260. **8:** 321-325. **9:** 148-163. **16:** 110-120. **19:** 119-209. **25:** 236-262. **30:** 59-65. **33:** 97-159.
5. **Electrotyping.** **1:** 291-293. **9:** 228-229.
6. **Electrolysis.** **5:** 173-178. **6:** 16-18. **8:** 261-262. **9:** 219-224. **12:** 158-170. **36:** 147-150.
7. **Dangers in Using Electricity.** **33:** 94-100. **34:** 168-177. **39:** 1-44.
8. **How to Make a Rheostat.** **1:** 125-155.
9. **How to Electroplate with Different Metals.** **1:** 266-290. **8:** 262-265. **12:** 158-170.
10. **How to Make an Electric Motor.** **1:** 255-265. **8:** 290-291. **14:** 132-135. **17:** 44-53. **21:** 318-333.
11. **How to Make a Small Dynamo.** **1:** 220-254.
12. **How to Make an Induction Coil.** **1:** 59-76.
13. **Homemade Push Buttons and Switches.** **1:** 33-54.
14. **Making Electromagnetic Toys.** **27:** 1-12. **27:** 26-30. **27:** 39-74.
15. **Electric Power on the Farm.** **2:** 3-31. **19:** (entire). **37:** (entire).
16. **Electric Trolley Cars and Railways.** **1:** 255. **8:** 296-298. **20:** 229-238. **28:** 54-62. **29:** 146-159.
17. **Electrical Engineering as a Vocation.** **24:** 89-98.
18. **How Electricity is Generated at Niagara.** **8:** 292-296. **18:** 169-171. **32:** 11-34.
19. **Electric Automobiles.** **40:** (entire).
20. **Electrical Measuring Instruments.** **1:** 102-121. **21:** 116-139. **34:** 25-43. **34:** 84-93.
21. **Discoverers and Inventors in Science.** (See also page 570.)
    Ampere, André. **4:** 67-69.
    Boyle, Robert. **11:** 100-113.
    Davy, Sir Humphrey. **13:** 226-247. **35:** 226-237.
    Edison, Thomas. **20:** (entire). **29:** 146-159.
    Faraday, Michael. **4:** 55-56. **4:** 71-86. **8:** 276-280. **11:** 159-169. **13:** 248-264. **35:** 226-237.
    Franklin, Benjamin. **4:** 46-50. **10:** 165-171. **11:** 109-123. **13:** 134-163. **35:** 66-89.
    Galvani, Luigi. **4:** 50-53. **8:** 251-258. **11:** 116-118. **12:** 158-170.
    Gilbert, William. **11:** 100-113. **11:** 34-41.
    Oersted, Hans. **4:** 55-67.
    Volta, Alessandro. **4:** 53-54. **8:** 251-258. **11:** 117-123. **12:** 158-170.

UNIT XV: LIGHTING OUR BUILDINGS AND STREETS

1. REFERENCES

(*A*) Books

1. Adams, J. H. Harper's Electricity Book for Boys
2. Allen, J. K. Sanitation in the Modern Home
3. Anderson, F. L. Electricity for the Farm
4. Baker, R. S. The Boys' Second Book of Inventions
5. Bond, A. R. The American Boys' Engineering Book
6. Burns, E. E. The Story of Great Inventions
7. Carpenter, F. G. How the World is Housed
8. Clarke, C. R. The Boys' Book of Chemistry
9. Collins, A. F. The Book of Stars
10. Collins, A. F. Wonders of Chemistry
11. Darrow, F. L. The Boys' Own Book of Great Inventions
12. Darrow, F. L. The Boys' Own Book of Science
13. Doubleday, R. Stories of Inventors
14. Earle, A. M. Home Life in Colonial Days
15. Forman, S. E. Stories of Useful Inventions
16. Gibson, C. R. The Romance of Modern Manufacture
17. Gibson, C. R. The Romance of Modern Photography
18. Godinez, F. L. The Lighting Book
19. Hall, A. N. Homemade Toys for Girls and Boys
20. Houston, E. J. The Wonder Book of Light
21. Iles, G. Flame, Electricity, and the Camera
22. Johnson, V. E. Modern Inventions
23. Koester, F. Electricity for the Farm and Home
24. Lescarboura, A. C. Behind the Motion Picture Screen
25. Meadowcroft, W. H. The Boy's Life of Edison
26. Mowry, W. A. and A. M. American Inventions and Inventors
27. Parkman, M. R. Conquests of Invention
28. Percival, G. A. The Electric Lamp Industry
29. Rolt-Wheeler, F. Thomas A. Edison
30. Williams, H. S. Science and Industry
31. Williams, A. How It Works
32. Williams, A. The Romance of Modern Invention
33. Williams, A. Thinking It Out
34. Willoughby. Practical Electricity for Beginners
35. Woodhull, J. F. Electricity and Its Everyday Uses

(*B*) Pamphlets and Bulletins

36. Agriculture Year Book Separate No. 770. "Electric Light and Power from Small Streams." 5¢.

Bureau of Standards Circulars:

37. No. 55. "Measurements for the Household." 25¢.
38. No. 70. "Materials for the Household." 25¢.

The Mentor:

39. "The Story of the Lens." 25¢.
40. "Photography." 25¢.

Eastman Kodak Company Pamphlets:

41. "Elementary Photographic Chemistry."
42. "How to Make Good Pictures."
43. "About Lenses."
44. "The Velox Book."
45. "By Flashlight."
46. The Mentor. "The History of the Motion Picture." 35¢.

2. GUIDE TO REFERENCES

(*A*) General

2: 238-250. **18:** 8-109. **20:** 257-269. **38:** 223-224.

(*B*) Specific Topics

1. **Gas Lighting.** **2:** 238-250. **26:** 61-89.
2. **Lighting with Electricity.** **3:** 172-191. **7:** 299-307. **23:** 210-224. **31:** 179-185. **34:** 39-46. **34:** 53-57. **36:** (entire). **38:** 227-228.
3. **Direct, Indirect, and Semi-Direct Lighting.** **33:** 302-304.
4. **Properties of Light—Speed, Intensity, Refraction, and Reflection.** **9:** 131-135. **20:** 8-34. **20:** 257-269. **33:** 298-315. **37:** 70-81.

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Early Methods of Lighting.** **7:** 278-281. **7:** 307-314. **11:** 299-306. **14:** 32-51. **15:** 28-37. **26:** 61-89.
2. **History of Electric Lighting.** **11:** 301-305. **21:** 121-134. **25:** (entire). **26:** 88-90. **30:** 154-160. **32:** 330-346.
3. **How Electric Lamp Bulbs Are Made.** **28:** 1-66. **28:** 95-109.
4. **A Homemade Transformer.** **11:** 282.
5. **How to Make an Arc Light.** **11:** 260-261.

6. **How to Make an Electric Light Filament Glow with an Electromagnet.** **11:** 281-282.
7. **Electric Lamp Industry.** **28:** (entire).
8. **How to Make an Electric Lamp.** **11:** 306-307.
9. **Electric Arc Lights (Cooper-Hewitt, Flaming Arc, and Ordinary Arc).** **1:** 336-338. **4:** 293-320. **28:** 67-94.
10. **The Acetylene Lamps.** **11:** 305-308.
11. **Lighting Circuit Troubles.** **34:** 72-81.
12. **Moving Pictures.** **13:** 113-131. **22:** 1-29. **24:** (entire). **29:** 157-175. **46:** (entire).
13. **Lenses and Their Uses.** **20:** 75-84. **39:** (entire). **43:** (entire).
14. **Making Gas Mantles.** **16:** 232-234.
15. **Mirrors and How They Work.** **20:** 35-50.
16. **Magnifying Lenses and the Miscroscope.** **31:** 254-256. **31:** 261-263.
17. **The Telescope.** **5:** 88-109. **6:** 9-18. **9:** 136-144. **11:** 367-377. **12:** 367-372. **31:** 257-261.
18. **Photography and the Camera.** **8:** 189-202. **10:** 164-171. **12:** 237-276. **17:** (entire). **31:** 233-246. **32:** 317-330. **40:** (entire). **41:** (entire). **42:** (entire). **43:** (entire). **44:** (entire). **45:** (entire).
19. **Discoverers and Inventors in Science.** (See also page 570.)
    Edison, Thomas. **11:** 301-303. **25:** (entire). **27:** 159-188. **30:** 154-160.
    Galilei, Galileo. **6:** 9-18. **12:** 367-372.

UNIT XVI: COMMUNICATING WITH OUR NEIGHBORS

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries
2. Adams, J. H. Harper's Electricity Book for Boys
3. Baker, R. S. The Boys' Book of Inventions
4. Baker, R. S. The Boys' Second Book of Inventions
5. Bond, A. R. The American Boys' Engineering Book
6. Bond, A. R. Inventions of the Great War
7. Bond, A. R. The Scientific American Boy
8. Bond, A. R. With the Men Who Do Things
9. Bragg, W. The World of Sound
10. Burns, E. E. The Story of Great Inventions
11. Caldwell, O. W. and Slosson, E. E. Science Remaking the World
12. Chamberlain, J. F. How We Travel
13. Cochrane, R. The Romance of Industry and Invention

14. Collins, A. F. The Book of Wireless Telegraph and Telephone
15. Collins, A. F. The Radio Amateur's Handbook
16. Collins, A. F. and V. The Boys' Book of Submarines
17. Collins, F. A. The Wireless Man
18. Corbin, T. The Romance of War Inventions
19. Corbin, T. The Romance of Submarine Engineering
20. Darrow, F. L. The Boys' Own Book of Great Inventions
21. Dorling, T. D. All about Ships
22. Doubleday, R. Stories of Inventors
23. DuPuy, W. A. Uncle Sam's Modern Miracles
24. Elliott, G. F. S. The Romance of Savage Life
25. Forman, S. E. Stories of Useful Inventions
26. Fournier d'Albe, E. E. Wonders of Physical Science
27. Gibson, C. R. The Romance of Modern Manufacture
28. Hall, A. N. Homemade Toys for Girls and Boys
29. Hall, A. N. Handicraft for Handy Boys
30. Haskin, F. J. The American Government
31. Holland, R. S. Historic Inventions
32. Iles, G. Flame, Electricity, and the Camera
33. Iles, G. Leading American Inventors
34. Johnson, V. E. Modern Inventions
35. Kendall, L. F. and Koehler, R. P. Radio Simplified
36. Koester, F. Electricity for the Farm and Home
37. Knox, G. D. All about Engineering
38. Lane, M. A. L. Triumphs of Science
39. Marriott, C. Uncle Sam's Business
40. Meadowcroft, W. H. The Boy's Life of Edison
41. Mills, J. Letters of a Radio-Engineer to His Son
42. Morgan, A. P. The Boy Electrician
43. Mowry, W. A. and A. M. American Inventions and Inventors
44. Parkman, M. R. Conquests of Invention
45. Percival, G. A. The Electric Lamp Industry
46. Reynolds, M. J. How Man Conquered Nature
47. Rocheleau, W. F. Great American Industries, Vol. III.
48. Seton, E. T. and Baden-Powell, Sir Robert. Boy Scouts of America: Official Handbook
49. Snodgrass, G. A. and Camp, V. F. Radio Receiving for Beginners
50. Tappan, E. M. Travelers and Traveling
51. Tappan, E. M. Makers of Many Things
52. Williams, H. S. The Conquest of Air and Ether
53. Williams, A. How It Works
54. Williams, A. The Romance of Modern Inventions
55. Woodhull, J. F. Electricity and Its Everyday Uses

(B) Pamphlets and Bulletins

56. Farmers' Bulletin No. 922. "Parcel Post Business Methods." 5¢.
57. Bureau of Census Intercensal Bulletin (1900-1924). "Telephones and Telegraphs." 10¢.
58. War Document No. 1069. "The Principles Underlying Radio Communication." $1.00.

2. GUIDE TO REFERENCES

(A) General

24: 278-291. **25:** 246-266. **43:** 247-294. **46:** 200-210.

(B) Specific Topics

1. **The Telegraph.** **42:** 150-170. **53:** 127-136. **55:** 59-68. **57:** (entire).
2. **The Electric Bell and Buzzer.** **1:** 60-67. **2:** 78-101. **42:** 140-150. **53:** 119-121. **55:** 69-73. **55:** 296-299.
3. **The Telephone.** **2:** 156-190. **20:** 61-71. **36:** 225-244. **42:** 170-193. **53:** 147-152. **55:** 93-95. **55:** 274-295. **57:** (entire).
4. **Wireless Telegraphy and Telephony.** **6:** 184-209. **10:** 208-225. **14:** (entire). **15:** (entire). **17:** (entire). **20:** 92-134. **35:** (entire). **41:** (entire). **42:** 237-238. **49:** 1-100. **53:** 137-146. **58:** (entire).
5. **Sound and Its Properties.** **9:** 1-30. **9:** 99-130.
6. **The Induction Coil and Transformer.** **28:** 124-132. **42:** 194-236. **53:** 121-123.
7. **The Electron Theory of the Electric Current.** **11:** 28-97.
8. **History of the Telegraph.** **10:** 126-139. **12:** 162-167. **13:** 269-295. **20:** 25-33. **26:** 124-136. **31:** 168-188. **32:** 177-192. **33:** 119-172. **43:** 270-277. **44:** 350-378. **52:** 1-31.
9. **History of the Telephone.** **10:** 139-147. **12:** 168-173. **20:** 40-60. **26:** 136-149. **31:** 215-232. **32:** 228-246. **43:** 286-292. **44:** 379-395. **52:** 69-102. **54:** 39-54.
10. **History of Wireless.** **3:** 79-117. **4:** 207-254. **18:** 240-250. **20:** 72-91. **22:** 1-26. **26:** 170-177. **34:** 206-231. **44:** 396-408. **52:** 49-68. **54:** 7-28.
11. **Submarine or Ocean Cables.** **8:** 240-254. **12:** 173-178. **19:** 226-272. **20:** 35-39. **32:** 193-201. **37:** 250-264. **38:** 1-13. **43:** 278-285. **52:** 32-48. **79:** 226-271.
12. **A Telephone Exchange.** **20:** 61-71. **22:** 181-198. **53:** 152-157.
13. **Duplex Telegraphy.** **20:** 33-35.

14. **Signalling by Light, by Semaphore, and by Other Methods.** **5:** 130-135. **7:** 144-157. **16:** 143-156. **21:** 246-258. **43:** 265-269. **48:** 54-62.
15. **Picture Writing of Early Days.** **25:** 227-245. **32:** 262-276. **43:** 247-251.
16. **History of Printing.** **1:** 185-198. **10:** 243. **25:** 227-245. **27:** 207-220. **31:** 9-41. **33:** 393-435. **43:** 252-257. **46:** 200-210. **47:** 160-221. **54:** 306-317.
17. **Making a Book.** **39:** 210-221. **47:** 222-236. **51:** 26-45.
18. **The United States Mail.** **1:** 185-190. **12:** 144-161. **13:** 247-269. **23:** 177-187. **30:** 131-150. **39:** 281-297. **50:** 15-25. **56:** (entire).
19. **The Phonograph.** **3:** 249-280. **10:** 147-149. **13:** 290-295. **53:** 310-321. **54:** 54-72.
20. **The Human Ear.** **53:** 271-277.
21. **Making a Telegraph at Home.** **2:** 190-200.
22. **Making a Wireless at Home.** **29:** 219-255.
23. **Discoverers and Inventors in Science.** (See also page 570.)
    Bell, Alexander. **10:** 140-146. **12:** 168-173. **20:** 40-49. **31:** 215-232. **44:** 379-395.
    De Forest, Lee. **10:** 221-224.
    Edison, Thomas. **6:** 118-125. **40:** (entire). **45:** xi-xxi.
    Field, Cyrus. **20:** 35-39.
    Gutenberg, Johann. **31:** 9-41.
    Marconi, Guglielmo. **3:** 79-117. **4:** 207-254. **10:** 208-220. **20:** 81-88. **22:** 1-26. **26:** 170-177. **44:** 396-408.
    Mergenthaler, Ottmer. **33:** 393-435.
    Morse, S. F. B. **10:** 126-136. **20:** 25-33. **31:** 168-188. **33:** 119-172. **44:** 350-378.
    Sholes, Christopher. **33:** 315-338.

UNIT XVII: TRANSPORTATION BY LAND, WATER, AND AIR

1. REFERENCES

(*A*) Books

1. Abbott, C. G. Everyday Mysteries
2. Baker, R. S. The Boys' Book of Inventions
3. Baker, R. S. The Boys' Second Book of Inventions
4. Bishop, F. The Story of the Submarine
5. Bond, A. R. On the Battlefront of Engineering
6. Bond, A. R. The American Boys' Engineering Book
7. Bond, A. R. Inventions of the Great War

8. Bond, A. R. The Scientific American Boy
9. Bond, A. R. The Scientific American Boy at School
10. Bond, A. R. With the Men Who Do Things
11. Brooks, E. C. The Story of Corn
12. Burns, E. E. The Story of Great Inventions
13. Camp, W. The Book of Sport and Games
14. Chamberlain, J. F. How We Travel
15. Cochrane, R. The Romance of Industry and Invention
16. Collins, A. F. and V. D. The Boys' Book of Submarines
17. Collins, A. F. The Book of Stars
18. Collins, A. F. Wonders of Chemistry
19. Collins, F. A. Sentinels Along Our Coast
20. Collins, F. A. The Air Man
21. Collins, F. A. Our Harbors and Inland Waterways
22. Cooke, A. O. A Day in a Shipyard
23. Corbin, T. The Romance of Submarine Engineering
24. Corbin, T. Marvels of Scientific Invention
25. Corbin, T. The Romance of War Inventions
26. Curtiss, G H. and Post, A. The Curtiss Aviation Book
27. Darrow, F. L. The Boys' Own Book of Great Inventions
28. Delacombe, H. The Boys' Book of Air Ships
29. Dorling, T. D. All about Ships
30. Doubleday, R. Stories of Inventors
31. DuPuy, W. A. Uncle Sam's Modern Miracles
32. Earle, A. M. Home Life in Colonial Days
33. Elliott, G. F. S. The Romance of Savage Life
34. Fabre, J. H. The Wonder Book of Chemistry
35. Forman, S. E. Stories of Useful Inventions
36. Fournier, d'Albe, E. E. Wonders of Physical Science
37. Gibson, C. R. The Romance of Modern Manufacture
38. Gibson, C. R. Heroes of Science
39. Goddard, D. Eminent Engineers
40. Hale, E. E. Stories of Invention
41. Hall, A. N. Homemade Toys for Girls and Boys
42. Hall, A. N. Handicraft for Handy Boys
43. Haskin, F. J. The American Government
44. Haskin, F. J. The Panama Canal
45. Holland, R. S. Historic Inventions
46. Houston, E. J. The Wonder Book of Magnetism
47. Howden, J. R. The Boys' Book of Steamships
48. Hubbard, T. O. and Turner, C. S. The Boys' Book of Aeroplanes
49. Husband, J. The Story of the Pullman Car
50. Iles, G. Flame, Electricity, and the Camera

51. Iles, G. Leading American Inventors
52. Jacoby, H. Practical Talks by an Astronomer
53. Johnson, V. E. Modern Inventions
54. Knox, G. D. All about Engineering
55. Lane, M. A. L. Triumphs of Science
56. Marriott, C. Uncle Sam's Business
57. Miller, C. M. Kite Craft
58. Moffett, C. Careers of Danger and Daring
59. Moody, J. The Railroad Builders
60. Morgan, A. P. Model Flying Machines
61. Morris, C. Home Life in All Lands, Book II
62. Mowry, W. A. and A. M. American Inventors and Inventions
63. Parkman, M. R. Conquests of Invention
64. Ravenel, S. W. Ravenel's Road Primer
65. Reid, W. and Others. Careers for Coming Men
66. Rocheleau, W. F. Great American Industries, Vol. 4
67. Seers, A. W. The Earth and Its Life
68. Simmonds, R. All About Air-Ships
69. Smith, L. Y. The Romance of Aircraft
70. Tappan, E. M. Travelers and Traveling
71. Thurstone, R. H. Robert Fulton
72. Turner, C. C. Aircraft of Today
73. Verne, Jules. Five Weeks in a Balloon
74. Verrill, A. H. The Ocean and Its Mysteries
75. Verrill, A. H. The Book of the Sail Boat
76. Warman, C. The Story of the Railroad
77. Williams, H. S. The Conquest of Air and Ether
78. Williams, H. S. The Conquest of Sea and Land
79. Williams, A. The Romance of Modern Locomotion
80. Williams, A. How It Works
81. Williams, A. The Romance of Modern Engineering
82. Williams, A. The Romance of Modern Invention
83. Williams, A. A Book of the Sea
84. Williams, A. Thinking It Out

(*B*) Pamphlets and Bulletins

Farmers' Bulletins:
85. No. 338. "Macadam Roads." 5¢.
86. No. 505. "Benefits of Improved Roads." 5¢.
87. No. 246. "Vitrified Brick Pavements for Country Roads." 10¢.
88. No. 660. "Highway Coast Keeping." 10¢.
89. No. 1077. "Portland Cement Concrete Roads." 15¢.
90. "Public Roads in the U. S." 10¢.

91. Agriculture Year Book Separate No. 727. "Design of Public Roads." 5¢.
92. Bureau of Education Bulletin No. 26. "Good Roads Arbor Day." 10¢.
93. U. S. Shipping Board Emergency Fleet Corporation. "Building of a Wooden Ship." 5¢.

Taylor Instrument Companies Pamphlets:
94. "Weather and Weather Instruments." 50¢.
95. "The Compass, the Signpost of the World." 10¢.

The Mentor:
96. "Conquest of the Air." 25¢.
97. "Aerial Navigation." 25¢.

2. GUIDE TO REFERENCES

(*A*) General

20: (entire). **26:** (entire). **29:** (entire). **48:** (entire). **62:** 187-244. **68:** (entire). **69:** (entire). **72:** (entire).

(*B*) Specific Topics

1. **Roads and Road Building.** **31:** 143-154. **54:** 85-99. **64:** (entire). **66:** 31-49. **70:** 108-120. **85:** (entire). **86:** (entire). **87:** (entire). **88:** (entire). **89:** (entire). **90:** (entire). **91:** (entire). **92:** (entire).
2. **Cutting Down Wind Resistance.** **84:** 230-240.
3. **Archimedes and the Principles of Buoyancy.** **12:** 6-7. **84:** 211-216.
4. **Sailboats.** **13:** 83-128. **66:** 53-64.
5. **Propelling Ships by Steam.** **12:** 244. **30:** 85-96. **47:** 78-120. **78:** 51-76.
6. **The Compass and Its Use.** **17:** 76-82. **19:** 255-272. **29:** 259-266. **36:** 34-49. **46:** 197-238. **55:** 147-154. **75:** 139-144. **78:** 1-14. **83:** 64-86. **94:** 142-156. **95:** (entire).
7. **The Log.** **29:** 267-274.
8. **Latitude and Longitude.** **17:** 82-87. **83:** 90-102.
9. **Balloons and Dirigibles.** **3:** 27-78. **7:** 148-168. **28:** 18-26. **53:** 47-68. **58:** 87-172. **68:** 32-62. **69:** (entire). **72:** 51-60. **73:** (entire). **97:** (entire)
10. **Airplanes—Their Construction and Operation.** **2:** 321-354. **25:** 284-296. **27:** 160-172. **48:** 1-72. **53:** 69-127. **60:** 5-17. **68:** 89-204. **69:** (entire). **72:** 117-148. **84:** 241-267. **97:** (entire).

3. TOPICS AND PROJECTS FOR INVESTIGATION

1. **Early Travel and Exploration.** **14:** 10-71. **21:** (entire). **33:** 266-277. **61:** 139-169. **62:** 187-206. **67:** 184-198.
2. **Ship Building and Launching.** **10:** 176-182. **22:** (entire). **25:** 184-239. **29:** 31-48. **29:** 188-196. **37:** 299-312. **47:** 25-63. **54:** 332-348. **55:** 84-99. **56:** 184-192. **81:** 308-333. **93:** (entire).
3. **Making a Canvas Canoe.** **8:** 109-123. **9:** 258-266.
4. **Building a Small Boat.** **9:** 18-27. **9:** 64-72. **9:** 297-308.
5. **The Work of the Ship's Crew.** **47:** 144-169.
6. **Types of Ships.** **7:** 298-310. **47:** 170-205. **66:** 206-280.
7. **History of Water Transportation.** **14:** 122-130 **15:** 215-245. **27:** 204-205. **29:** 1-31. **35:** 191-210. **39:** 18-48. **40:** 172-192. **45:** 111-125. **47:** 1-25. **47:** 63-77. **51:** 3-75. **62:** 206-222. **63:** 222-241. **67:** 184-198. **71:** (entire). **75:** 1-10. **83:** 9-65.
8. **Submarines and Their Operation.** **2:** 1-39. **4:** 3-123. **7:** 232-276. **7:** 310-339. **10:** 197-213. **12:** 190-198. **16:** (entire). **23:** 67-141. **24:** 78-108. **25:** 223-239. **27:** 173-193. **36:** 153-180. **53:** 30-46. **55:** 69-83. **78:** 77-97. **82:** 143-166.
9. **Inland Water Transportation.** **11:** 167-182. **13:** 129-141. **21:** 199-218. **66:** 110-147. **70:** 82-94. **81:** 245-267.
10. **Docks and Dry Docks.** **10:** 183-196. **23:** 179-195. **29:** 212-220. **54:** 349-357. **81:** 333-349.
11. **Harbors.** **21:** (entire).
12. **Flags at Sea.** **29:** 235-245.
13. **Lighthouses and Light-Ships.** **3:** 255-292. **19:** (entire). **29:** 307-317. **54:** 283-301. **55:** 49-56. **74:** 80-99. **75:** 125-138. **83:** 120-206.
14. **Sound Warnings at Sea.** **83:** 207-231.
15. **Life Boats and Their Work.** **30:** 97-112. **83:** 232-270.
16. **Aircraft in War.** **7:** 123-148. **43:** 171-178. **48:** 79-112. **72:** 215-279.
17. **How to Make a Model Airplane.** **27:** 167-172. **41:** 21-33. **42:** 297-326. **60:** (entire). **68:** 333-337.
18. **Kites.** **2:** 205-247. **27:** 156-160. **41:** 9-21. **57:** (entire).
19. **How to Make a Glider.** **9:** 187-197.
20. **Famous Balloon Races.** **28:** 48-50.
21. **Sensations During Flying.** **68:** 271-299. **72:** 149-173.
22. **History of Air Transportation.** **12:** 173-190. **12:** 237. **14:** 138-144. **26:** (entire). **27:** 134-155. **28:** 2-13. **30:** 27-51. **36:** 190-201. **48:** 89-201. **63:** 325-329. **63:** 330-346. **68:** 1-181. **72:** 11-35. **72:** 74-82. **77:** 103-190. **82:** 284-306. **96:** (entire).

23. **History of Land Transportation.** **1:** 68-76. **11:** 183-196. **14:** 107-110. **15:** 192-204. **35:** 168-190. **40:** 193-218. **49:** 1-39. **63:** 310-324. **66:** 5-31. **78:** 126-127. **79:** 250-267.
24. **The Story of the Pullman Car.** **49:** (entire).
25. **Block Signaling on Railroads.** **70:** 1-14. **79:** 174-189. **80:** 201-229.
26. **Bridge Building.** **5:** 183-210. **8:** 95-108. **8:** 292-310. **9:** 121-140. **10:** 98-109. **30:** 131-152. **54:** 216-242. **58:** 173-208. **81:** 82-127.
27. **Electric Railways.** **12:** 110-117. **27:** 296-298. **50:** 162-176. **66:** 229-233.
28. **Railroad Tunnels.** **55:** 100-119. **81:** 204-225.
29. **Building and Operating Railroads.** **54:** 302-309. **59:** (entire). **62:** 223-229. **65:** 73-82. **66:** 148-226. **70:** 1-14. **70:** 36-43. **70:** 63-73. **76:** (entire). **79:** 164-173. **79:** 228-297. **81:** 139-182.
30. **Transportation and Travel in Colonial Times.** **14:** 10-14. **32:** 325-363.
31. **Helium Gas.** **18:** 78-81.
32. **The Construction of Locomotives.** **79:** 268-287.
33. **The Development of the Modern Locomotives.** **51:** 218-275. **63:** 139-158. **63:** 242-274.
34. **Causes of Railroad Accidents.** **79:** 220-214.
35. **Interesting Railroads.** **79:** 18-128. **79:** 153-163. **79:** 215-234.
36. **The Panama Canal.** **44:** (entire). **54:** 12-28. **81:** 267-292.
37. **How to Make a Model Submarine.** **16:** 23-51.
38. **Methods of Travel in Foreign Lands.** **14:** 10-100.
39. **How to Make a Periscope.** **27:** 191-193.
40. **The Gyroscope and Gyro-Car.** **27:** 1-24. **78:** 160-190.
41. **Navigating Instruments.** **52:** 1-9. **78:** 14-24. **94:** 142-156.
42. **Homemade Toy Railway.** **6:** 142-177. **41:** 47-59
43. **Discoverers and Inventors in Science.** (See also page 570.)

    Archimedes. **12:** 1-8. **36:** 1-11.
    Ericsson, John. **61:** 218-275.
    Dumont, Santos. **30:** 27-51.
    Ford, Henry. **63:** 310-324.
    Fulton, Robert. **39:** 43-48. **40:** 172-192. **45:** 111-125. **51:** 40-75. **63:** 222-241. **71:** (entire). **78:** 51-76.
    Gilbert, William. **26:** 34-41.
    Langley, S. P. **36:** 190-201. **63:** 325-329. **77:** 155-190.
    Montgolfier Brothers. **36:** 190-201. **77:** 103-154.
    Murdock, William. **63:** 139-158.
    Stephenson, G. **12:** 155-163. **39:** 207-216. **40:** 193-218. **63:** 242-274.
    Stevens, John and Robert L. **51:** 3-40.
    Wright, Wilbur and Orville. **63:** 330-346. **77:** 155-190.
    Zeppelin, Count. **36:** 190-201.

DISCOVERERS AND INVENTORS IN SCIENCE

1. REFERENCES

1. Allen, G. Charles Darwin
2. Bolton, H. C. Evolution of the Thermometer
3. Burns, E. E. The Story of Great Inventions
4. Caldwell, O. W. and Slosson, E. E. Science Remaking the World
5. Carnegie, A. James Watt
6. Chamberlain, J. F. How We Travel
7. Cooper, F. T. Thomas A. Edison
8. Darrow, F. L. The Boys' Own Book of Great Inventions
9. Darrow, F. L. Masters of Science and Invention
10. Fournier, d'Albe, E. E. Wonders of Physical Science
11. Franklin, Benjamin. The Autobiography of Benjamin Franklin
12. Gibson, C. R. Heroes of Science
13. Goddard, D. Eminent Engineers
14. Hale, E. E. Stories of Invention
15. Holden, E. S. Stories of the Great Astronomers
16. Holland, R. S. Historic Inventions
17. Hubert, P. G. Inventors
18. Iles, G. Leading American Inventors
19. Jones, F. A. Thomas Alva Edison—Sixty Years in an Inventor's Life
20. Kelly, H. A. Walter Reed and Yellow Fever
21. Lodge, Sir Oliver. Pioneers of Science
22. Meadowcroft, W. H. The Boy's Life of Edison
23. Paget, S. Pasteur and after Pasteur
24. Parkman, M. R. Heroes of Today
25. Parkman, M. R. Conquests of Invention
26. Pearson, E. C. Gutenberg and the Art of Printing
27. Percival, G. A. The Electric Lamp Industry
28. Philip, J. C. Achievements of Chemical Science
29. Thurstone, R. H. Robert Fulton
30. Towers, W. K. Masters of Space
31. Vallery-Radot, R. The Life of Pasteur
32. Williams, H. S. The Conquest of Sea and Land
33. Williams, H. S. Tribute from the Animal World
34. Williams, H. S. Tribute from the Mineral World
35. Williams, H. S. Science and Industry
36. Williams, H. S. The Conquest of Air and Ether
37. Wright, H. C. Children's Stories of the Great Scientists

2. GUIDE TO REFERENCES

Ampere, André (Electromagnetism). **3:** 67-69.

Arkwright, Sir Richard (Spinning frame). **9:** 44-47. **13:** 151-154.

Archimedes (Lever, density, water screw, endless screw, buoyancy). **3:** 1-8. **10:** 1-11.

Bell, Alexander Graham (Telephone). **3:** 140-146. **6:** 168-172. **8:** 40-49. **9:** 281-293. **10:** 136-149. **16:** 215-232. **17:** 264-269. **25:** 379-395. **30:** 151-187.

Bessemer, Sir Henry (Steel). **9:** 172-180. **13:** 265-271. **34:** 49-51.

Carroll, James, Dr. (Yellow fever). **20:** 272-281.

Carty, John (Telephone switchboards). **30:** 231-249.

Cavendish, Henry (Chemistry of gases, electricity, density of the earth). **12:** 179-187.

Clark, Alvan (Telescope lenses). **9:** 135-139.

Dalton, John (Chemistry). **12:** 214-225.

De Forest, Lee (Radio tube). **3:** 221-224. **30:** 250-263.

Davy, Sir Humphrey (Safety lamp, electrolysis, arc lamp). **12:** 226-247. **37:** 212-225.

Edison, Thomas A. (Telegraph, electric light, cement, phonograph). **3:** 118-125. **7:** (entire). **8:** 301-303. **9:** 265-280. **10:** 149-159. **17:** 223-263. **19:** (entire). **22:** (entire). **27:** xi-xxi. **35:** 154-160.

Einstein, Albert (Gravity). **9:** 18-26.

Ericsson, John (Locomotive). **18:** 218-275.

Fahrenheit, Gabriel (Thermometer). **2:** 66-79.

Faraday, Michael (Dynamo). **3:** 55-56; 71-86. **8:** 276-280. **9:** 73-77. **10:** 159-169. **12:** 248-264. **37:** 226-237.

Field, Cyrus W. (Ocean Cable). **8:** 35-39. **30:** 106-150.

Ford, Henry (Automobile). **25:** 310-324.

Franklin, Benjamin (Electricity, lightning rod, almanac). **3:** 46-50. **7:** (entire). **10:** 100-123. **11:** (entire). **12:** 134-163. **13:** 9-16. **17:** 9-44. **19:** (entire). **37:** 66-89.

Fulton, Robert (Steamboat). **9:** 103-106. **13:** 43-48. **14:** 172-192. **17:** 45-68. **18:** 40-75. **25:** 222-241. **32:** 51-76.

Galilei, Galileo (Clock, falling bodies, telescope, thermometer). **2:** 14-25. **3:** 9-18. **8:** 367-372. **9:** 3-12. **10:** 50-64; 65-69. **12:** 76-106. **16:** 53-69. **37:** 1-34.

Galvani, Luigi (Electricity). **3:** 50-53. **8:** 251-258. **10:** 116-118.

Gilbert, William (Compass, earth as a magnet). **10:** 34-49. **10:** 100-113.

Goodyear, Charles (Vulcanization of rubber). **17**: 178-206. **18**: 176-218. **25**: 110-134.

Guericke, Otto von (Air pump). **3**: 20-22. **10**: 80-88.

Gutenberg, Johann (Printing). **16**: 9-41. **26**: (entire).

Hargreaves, James (Spinning jenny). **9**: 41-44. **25**: 38-48.

Henry, Joseph (Electromagnet). **9**: 140-147.

Herschel, William and Caroline (Reflecting telescope, astronomy). **9**: 58-63. **12**: 188-213. **21**: 274-293. **37**: 114-137.

Holland, John P. (Submarine). **9**: 306-313.

Howe, Elias (Sewing machine). **13**: 79-84. **16**: 206-214. **17**: 99-110. **25**: 87-106. **35**: 75-90.

Jenner, Edward (Smallpox vaccine). **9**: 125-127.

Kelly, William (Bessemer steel). **25**: 310-324.

Kepler, Johann (Planets). **12**: 67-71. **37**: 35-48.

Langley, Samuel P. (Airplane). **10**: 190-201. **24**: 233-259. **25**: 325-329. **36**: 155-190.

La Place, Pierre de (Solar system). **9**: 63-66.

Lavoisier, Antoine (Oxygen, balance). **9**: 37-40. **28**: 32-40.

Lazear, Jesse, Dr. (Yellow fever). **20**: 281-288.

Lister, Joseph (Antiseptic surgery). **23**: 32-45.

Marconi, Guglielmo (Wireless telegraphy and telephony). **3**: 208-220. **8**: 81-88. **9**: 294-305. **10**: 170-177. **25**: 396-408. **30**: 199-230.

McCormick, Cyrus (Reaper). **16**: 189-205. **17**: 207-222. **18**: 276-315. **25**: 8-28.

Morse, Samuel (Telegraph). **3**: 126-136. **6**: 162-167. **8**: 25-33; 35-39. **9**: 148-157. **16**: 168-188. **17**: 111-154. **18**: 119-172. **25**: 350-378. **30**: 40-106.

Montgolfier Brothers (Balloon). **10**: 190-201. **36**: 103-154.

Murdock, William (Gas generator, locomotives). **25**: 139-158.

Newcomen, Thomas (Air engine). **3**: 36-38.

Newton, Isaac (Gravity, light). **9**: 13-17. **12**: 107-133. **37**: 49-65.

Papin, Denis (Steam engine). **3**: 34-35. **10**: 88-100.

Pascal, Blaise (Air pressure). **3**: 25-27.

Pasteur, Louis (Germ theory of disease, vaccination). **4**: 133-149. **9**: 186-197. **23**: 32-45. **31**: (entire). **33**: 38-43.

Priestley, Joseph (Phlogiston, oxygen). **9**: 27-33. **12**: 164-178. **28**: 1-14.

Reed, Walter (Yellow fever). **20**: (entire).

Rumford, Benjamin (Friction). **37**: 138-153.

Scheele, Karl Wilhelm (Oxygen). **9:** 33-35.

Sholes, Christopher (Typewriter). **18:** 315-338.

Stephenson, George (Locomotive). **3:** 155-163. **9:** 106-110 **13:** 207-216. **16:** 140-167. **25:** 242-244. **32:** 98-118; 51-76.

Stevens, John and Robert (Screw propeller, sectional boiler). **18:** 3-40.

Telghman, Benjamin (Paper from wood). **18:** 369-393.

Thompson, William, Lord Kelvin (Ocean cable). **30:** 106-150.

Torricelli, Evangelista (Air pressure, barometer). **3:** 19-20. **10:** 65-79.

Volta, Alessandro (Electric cell). **3:** 53-54. **8:** 251-258. **10:** 117-123.

Watt, James (Steam engine). **3:** 38-42. **5:** (entire). **8:** 194-206. **9:** 99-103. **13:** 161-166. **16:** 70-83. **25:** 191-216.

Westinghouse, George (Air brake). **9:** 253-264. **25:** 275-292. **32:** 118-126.

Whitney, Eli (Cotton gin). **9:** 53-57. **13:** 61-69. **13:** 97-110. **17:** 69-98. **18:** 75-104. **25:** 63-79.

Wright, Orville and Wilbur (Airplane). **9:** 315-325. **10:** 190-201. **25:** 330-346. **36:** 155-190.

Zeppelin, Count (Dirigible). **10:** 190-201.

PRONUNCIATION LIST

Note to Students. This is a list of the important scientific words and proper names found in the text which may be difficult for you to pronounce. Following each of the terms and names you will find the proper pronunciation. Though some words have more than one pronunciation, it will be well for you to use the one here given. Foreign proper names are here marked as they are pronounced in foreign countries. The marked letters are sounded according to the letters in the following list of sample words as given in Webster's Dictionary.

āle, senâte, câre, ăm, ärm, sofȧ;
ēve, ēvent, ĕnd, makẽr;
fo͞od, fo͝ot;
īce, ĭll;
ink;

ōld, ōbey, ôrb, ŏdd, côrn;
out, oil, nature, verdure;
ūse, ûnite, ûrn, ŭp, menü;
zh = z as in azure. Jeaṅ (nasal), cañyon.

Abscess (ăb′sĕs)
Absorb (ăb-sôrb′)
Acetylene (ȧ-sĕt′ĭ-lēn)
Adulterating (ȧ-dŭl′tẽr-āt-ĭng)
Aedes (ȧ-e′dēz)
Aerator (ā′ẽr-ā′tẽr)
Aerial (ā-ē′rĭ-ăl)
Alcohol (ăl′kō-hŏl)
Alkali (ăl′kȧ-lī)
Altair (ăl-tä′ĭr)
Alternation (ăl′tẽr-nā′shŭn)
Altitude (ăl′tĭ-tūd)
Ammonia (ă-mō′nĭ-ȧ)
Ammonium (ă-mō′nĭ-ŭm)
Ampere (ăm-pâr′)
Analysis (ȧ-năl′ĭ-sĭs)
Andromeda (ăn-drŏm′-ē-dȧ)
Annealing (ă-nēl′ĭng)
Anopheles (ȧ-nŏf′ē-lēz)
Antares (ăn-tā′rēz)
Anthracite (ăn′thrȧ-sīt)
Anti-body (ăn′tĭ-bŏd′ĭ)
Antiseptic (ăn′tĭ-sĕp′tĭk)
Antitoxin (ăn′tĭ-tŏk′sĭn)
Aquarius (ȧ-kwā′rĭ-ŭs)
Aqueous (ā′kwē-ŭs)
Aquila (ăk′wĭ-lȧ)
Arc (ärk)
Arcturus (ärk-tū′rŭs)
Aries (ā′rĭ-ēz)
Armature (är′mȧ-tûr)
Artesian (är-tē′zhăn)
Artificial (är′tĭ-fĭsh′ăl)
Astronomer (ăs-trŏn′ō-mẽr)
Auriga (ô-rī′ga)
Automatic (ô′tō-măt′ĭk)

Bacteria (băk-tē′rĭ-ȧ)
Barometer (bȧ-rŏm′ē-tẽr)
Bevel (bĕv′ĕl)
Bicarbonate (bī-kär′bŏn-āt)
Bisque (bĭsk)
Bituminous (bĭ-tū′mĭ-nŭs)
Boötes (bō-ō′tēz)

Borax (bō′răks)
Bronchi (brŏn′kī)
Buoyancy (boi′ăn-sĭ)
Bureau (bū′rō)

Caisson (kā′sŏn)
Calcium (kăl′sĭ-ŭm)
Calorie (kăl′ō-rĭ)
Capacity (kȧ-păs′ĭ-tĭ′)
Capella (kȧ-pĕl′ȧ)
Capillarity (kăp′ĭ-lăr′ĭ-tĭ)
Capricornus (kăp′rĭ-kôr′nŭs)
Capstan (kăp′stăn)
Carbohydrate (kär′bō-hī′drāt)
Carburetor (kär′bū-rĕt′ẽr)
Cassiopeia (kăs′ĭ-ō-pē′yȧ)
Cement (sē-mĕnt′)
Centigrade (sĕn′tĭ-grād)
Centimeter (sĕn′tĭ-mē′tẽr)
Centrifugal (sĕn-trĭf′ū-găl)
Cepheus (sē′fūs)
Cetus (sē′tŭs)
Chlorination (klō′rĭ-nă-shŭn)
Chlorine (klō′rĭn)
Chloroform (klō′rōfôrm)
Chlorophyll (klō′rō-fĭl)
Chord (kôrd)
Choroid (kō′roid)
Chronometer (krō-nŏm′ē-tẽr)
Ciliated (sĭl′ĭ-āt′ĕd)
Circuit (sûr′kĭt)
Cirrus (sĭr′ŭs)
Clermont (klĕr′mŏnt)
Climatological (klī′mȧtŏl′ō-jĭ-căl)
Cobalt (kō′bôlt)
Combustible (kŏm-bŭs′tĭ-b′l)
Comet (kŏm′ĕt)
Communicable (kō-mū′nĭ-kȧ-b′l)
Commutator (kŏm′ū-tā′tẽr)
Composition (kŏm′pō-zĭsh′ŭn)
Compressibility (kŏm-prĕs′ĭ-bĭl′ĭ-tĭ)
Conductivity (kŏn′dŭk-tĭv′ĭ-tĭ)
Condense (kŏn-dĕns′)
Condensation (kŏn′dĕn-sā′shŭn)
Conduit (kŏn′dĭt)
Constellation (kŏn′stĕ-lā′shŭn)
Contagious (kŏn-tā′jŭs)
Contaminate (kŏn-tăm′ĭ-nāt)

Contract (kŏn-trăkt′)
Convection (kŏn-vĕk′shŭn)
Cornea (kôr′nē-ȧ)
Corona (kō-rō′nȧ)
Corpuscle (kôr′pŭs-′l)
Crystalline (krĭs′tăl-ĭn)
Cugnot (kū-ñyō′)
Culex (kū′lĕks)
Culture (kŭl′-tûr)
Cumulus (kū′mū-lŭs)
Curvilinear (kûr′vĭ-lĭn′ē-ȧr)
Cycle (sī′kl)
Cygnus (sĭg′nŭs)
Cylinder (sĭl′ĭn-dẽr)

Decomposition (dē-kŏm′pō-zĭ′shŭn)
Demurrage (dē-mŭr′āj)
Diagnose (dī′ăg-nōs′)
Disease (dĭ-zēz′)
Disinfect (dĭs′ĭn-fĕkt′)
Distillation (dĭs′tĭ-lā′shŭn)
Diameter (dī-ăm′-ē-tẽr)
Diaphragm (dī′ȧ-frăm)
Diarrhea (dī′ȧ-rē′ȧ)
Diet (dī′ĕt)
Differential (dĭf-ẽr-ĕn′shăl)
Diffusion (dĭ-fū′zhŭn)
Digestible (dĭ-jĕs′ti-b′l)
Diphtheria (dĭf-thē′rĭ-ȧ)
Dirigible (dĭr′ĭ-jĭ-b′l)
Draco (drā′kō)
Duct (dŭkt)
Durability (dū′rȧ-bĭl′ĭ-tĭ)
Dynamo (dī′nȧ-mō)
Dysentery (dĭs′ĕn-tĕr-ĭ)

Eccentric (ĕk-sĕn′trĭk)
Eclipse (ē-klĭps′)
Efficiency (ĕ-fĭsh′ĕn-sĭ)
Electrified (ē-lĕk′trĭ-fīd)
Electrode (ē-lĕk′trōd)
Electrolyte (ē-lĕk′trō-līt)
Electromotive (ē-lĕk′trō-mō′tĭv)
Electrons (ē-lĕk′trŏn)
Emulsion (ē-mŭl′shŭn)
Enteritis (ĕn′tẽr-ĭ′tĭs)
Epidemic (ĕp′ĭ-dĕm′ĭk)
Epithelial (ĕp-ĭ-thē′lĭ-ăl)

Esophagus (ē̇-sŏf′ȧ-gŭs)
Ether (ē′thẽr)
Evaporation (ē̇-văp′ō-rā′shŭn)
Excretory (ĕks′krē̇-tō̇-rĭ)
Extinguisher (ĕ̇ks-tĭn′gwĭsh-ẽr)

Fahrenheit (fä′rĕn-hīt)
Fehling (fā′lĭng)
Fermentation (fûr′mĕn-tā′shŭn)
Fertilizing (fûr′tĭ-līz-ĭng)
Flume (flo͞om)
Fomalhaut (fō′măl-hôt)
Friction (frĭk′shŭn)
Fulcrum (fŭl′krŭm)
Fumigate (fū′mĭ-gāt)
Fuse (fūz)
Fuselage (fū′zē̇-lȧj)

Galileo (găl′lē-lā′ō)
Gastric (găs′trĭk)
Generator (jĕn′ẽr-ā′tẽr)
Germicide (jûr′mĭ-sīd)
Glacier (glā′shẽr)
Glycerine (glĭs′ẽr-ĭn)
Gravity (grăv′ĭ-tĭ)
Greenwich (grĭn′ĭj)

Halo (hā′lō)
Helium (hē′lĭ-ŭm)
Hemisphere (hĕm′ĭ-sfēr)
Hercules (hûr′kū̇-lēz)
Herschel (hûr′shĕl)
Humid (hū′mĭd)
Humidity (hū̇-mĭd′ĭ-tĭ)
Hydrochloric (hī′drō-klō′rĭk)
Hydraulic (hī-drô′lĭk)
Hydrocarbon (hī′drō-kär′bŏn)
Hydrometer (hī-drŏm′ē̇-tẽr)
Hydrophobia (hī′drō̇-fō′bĭ-ȧ)
Hydroxide (hī-drŏk′sīd)

Igloo (ĭg′lo͞o)
Igneous (ĭg′nē̇-ŭs)
Illumination (ĭ-lū′mĭ-nā′shŭn)
Immune (ĭ-mūn′)
Incandescent (ĭn′kăn-dĕs′ĕnt)
Incidence (ĭn′sĭ-dĕns)
Inclination (ĭn′klĭ-nā′shŭn)
Incombustible (ĭn′kŏm-bŭs′tĭ-b'l)
Induced (ĭn-dūst′)
Induction (ĭn-dŭk′shŭn)
Inertia (ĭn-ûr′shĭ-ȧ)
Inflamed (ĭn-flāmd′)
Influenza (ĭn′flo͞o-ĕn′-zȧ)
Ingredient (ĭn-grē′dĭ-ĕnt)
Insulated (ĭn′sū̇-lāt′ĕd)
Intensity (ĭn-tĕn′sĭ-tĭ)
Interference (ĭn′tẽr-fēr′ĕns)
Iodine (ī′ō̇-dĭn)
Isobar (ī′sō̇-bär)
Isotherm (ī′sō̇-thûrm)

Jenner (jĕn′ẽr)
Jupiter (jo͞o′pĭ-tẽr)

Kiln (kĭl)
Kilogram (kĭl′ō̇-grăm)
Kilometer (kĭl′ō-mē′tẽr)
Kilowatt (kĭl′ō-wŏt)

Larva (lär′vȧ)
Larynx (lăr′ĭnks)
Lavoisier (lȧ′vwȧ′zyā′)
Lazear (lȧ-zēr′)
Lever (lē′vẽr)
Leviathan (lē̇-vī′ȧ-thăn)
Los Angeles (lōs ăn′gĕl-ĕs)
Lubrication (lū′brĭ-kā′shŭn)
Luminous (lū′mĭ-nŭs)
Lunar (lū′nȧr)
Lymph (lĭmf)
Lyra (lī′rȧ)

Machine (mȧ-shēn′)
Maggot (măg′ŏt)
Magnetism (măg′nĕt-ĭz'm)
Malarial (mȧ-lā′rĭ-ȧl)
Mantle (măn′t'l)
Marconi (mär-kō′nē)
Mars (märz)
Mechanical (mē̇-kăn′-ĭ-kăl)
Medullary (mĕd′ŭ-lā-rĭ)
Mercury (mûr′kū̇-rĭ)
Meridian (mē̇-rĭd′ĭ-ăn)
Metamorphic (mĕt′ȧ-môr′fĭk)
Meteor (mē′tē̇-ŏr)

Meter (mē'tẽr)
Metric (mĕt'rĭk)
Microphone (mī'krō-fōn)
Microscope (mī'krō-skōp)
Millimeter (mĭl'ĭ-mē'tẽr)
Molecule (mŏl'ē-kūl)
Molybdenum (mō-lĭb'dē-nŭm)
Montgolfier (môn'gōl'fyā')
Mortality (mŏr-tăl'ĭ-tĭ)
Mucous (mū'kŭs)
Murdock (mûr'dŏk)

Naphtha (năf'thȧ)
Nebula (nĕb'ū-lȧ)
Neptune (nĕp'tūn)
Nimbus (nĭm'bŭs)

Observatory (ŏb-zûr'vȧ-tō-rĭ)
Ohm (ōm)
Oöcyst (ō'ō-sĭst)
Opaque (ō-pāk')
Ophiuchus (ŏf'ĭ-ū'kŭs)
Orbit (ôr'bĭt)
Organism (ôr'găn-ĭzm)
Oscillate (ŏs'ĭ-lāt)
Oxygen (ŏk'sĭ-jĕn)
Oxidation (ŏk'sĭ-dā'shŭn)

Pancreas (păn'krē-ăs)
Parachute (păr'ȧ-shōōt)
Paraffin (păr'ă-fĭn)
Parasite (păr'ȧ-sīt)
Partial (pär'-shăl)
Pasteur (pȧs'tûr')
Pasteurization (pȧs'tẽr-ĭ-zā'shŭn)
Pathogenic (păth'ō-jĕn'ĭk)
Pegasus (pĕg'ȧ-sŭs)
Pelton (pĕl'tŭn)
Perseus (pûr'sūs)
Perspiration (pûr'spĭ-rā'shŭn)
Petri (pē'trĭ)
Petroleum (pē-trō'lē-ŭm)
Pharynx (făr'ĭnks)
Phase (fāz)
Pisces (pĭs'ēz)
Planet (plăn'ĕt)
Planetoid (plăn'ĕt-oid)
Plastic (plăs'tĭk)
Plateau (plȧ-tō')
Pliers (plī'ẽrs)
Pneumatic (nū-măt'ĭk)
Polaris (pō-lā'rĭs)
Pollute (pŏ-lūt')
Porous (pō'rŭs)
Precipitate (prē-sĭp'ĭ-tāt)
Pressure (prĕsh'ûr)
Primary (prī'mȧ-ri)
Propeller (prō-pĕl'ẽr)
Protein (prō'tē-ĭn)
Protoplasm (prō'tō-plăsm)
Pupa (pū'pȧ)
Pus (pŭs)
Ptomaine (tō'mâ-ĭn)

Quarantine (kwŏr'ăn-tēn)
Quarried (kwŏr'ĭd)
Quartz (kwôrts)

Rabies (rā'bĭ-ēz)
Radiant (rā'dĭ-ănt)
Ratio (rā'shĭ-ō)
Ration (rā'shŭn)
Reënforce (rē'ĕn-fōrs')
Reflect (rē-flĕkt')
Reflection (rē-flĕk'shŭn)
Relay (rē lā')
Reservoir (rĕz'ẽr-vwôr)
Resistance (rē-zĭs'tăns)
Respiratory (rē-spīr'ȧ-tō-rĭ)
Retina rĕt'ĭ-nȧ)
Rheostat (ré'ō-stăt)
Rozier (rō-zē-ā')
Rotor (rō'tŏr)

Sagittarius (săj-ĭ-ta'rĭ-ŭs)
Salivary (săl'ĭ-vâ-rĭ)
Sanitary (săn'ĭ-tâ-rĭ)
Santa Maria (săn'tȧ mȧ-rē'ȧ)
Satellite (săt'ĕ-līt)
Saturn (săt'ŭrn)
Sclerotic (sklē-rot'ĭk)
Scorpio (skôr'pĭ-ō)
Sedentary (sĕd'ĕn-tâ-rĭ)
Sedimentary (sĕd'ĭ-mĕn'tȧ-rĭ)
Seguin (sā găn')
Septic (sĕp'tĭk)

Sera (sē′rȧ)
Serpens (sûr′pĕnz)
Sewage (sū′âj)
Sewer (sū′ẽr)
Sextant (sĕks′tănt)
Shenandoah (shĕn′ăn-dō′ȧ)
Siphon (sī′fŏn)
Slaked (slākt)
Solar (sō′lȧr)
Solder (sŏd′ẽr)
Soluble (sŏl′ū-b′l)
Speedometer (spēd-ŏm′ḗ-tẽr)
Sphere (sfēr)
Spiral (spī′răl)
Spur (spûr)
Sputum (spū′tŭm)
Static (stăt′ĭk)
Stator (stā′tŏr)
Sterilize (stĕr′ĭ-līz)
Stomates (stō′māts)
Stratus (strā′tŭs)
Stucco (stŭk′ō)
Sulphuric (sŭl-fū′rĭk)
Symptom (sĭmp′tŭm)

Tangential (tăn-jĕn′shăl)
Telegraph (tĕl′ḗ-grȧf)
Telegraphy (tḗ-lĕg′rȧ-fĭ)
Telephone (tĕl′ḗ-fōn)
Telephonic (tĕl′ē-fŏn′ĭk)
Telescope (tĕl′ḗ-skōp)
Temperature (tĕm′pẽr-ȧ-tûr)
Tetanus (tĕt′ȧ-nŭs)
Tetrachloride (tĕt′rȧ-chlŏr′īd)
Thermograph (thûr′mŏ-grȧf)
Thermometer (thẽr-mŏm′ḗ-tẽr)
Thermostat (thûr′mŏ-stăt)
Tissue (tĭsh′ū)
Topography (tŏ-pŏg′rȧ-fĭ)
Torricelli (tŏr′rē-chĕl′lē)
Toxins (tŏk′sĭns)
Toxaemia (tōk-sē′mĭ-ȧ)

Trachea (trā′kḗ-ȧ)
Traction (trăk′-shŭn)
Translucent (trăns-lū′sĕnt)
Transmitter (trăns-mĭt′ẽr)
Transparency (trăns-pâr′ĕn-sĭ)
Triangulum (trī-ăn′gū-lŭm)
Trichina (trĭ-kī′nȧ)
Tsetse (tsĕt′sĕ)
Tuberculosis (tū-bûr′kū-lō′sĭs)
Turbinate (tûr′bĭ-nāt)
Typhus (tī′fŭs)

Universe (ū′nĭ-vûrs)
Uranus (ū′rȧ-nŭs)
Ursa Major (ûr′sȧ mā′jẽr)
Ursa Minor (ûr′sȧ mī′nẽr)
Utilize (ū′tĭ-līz)

Vaccination (văk′sĭ-nā′shŭn)
Vaccine (văk′sĭn)
Vacuum (văk′ū-ŭm)
Vane (vān)
Vapor (vā′pẽr)
Vaporize (vā′pẽr-īz)
Vega (vē′gȧ)
Ventilation (vĕn′tĭ-lā′shŭn)
Venus (vē′nŭs)
Vibrate (vī′brāt)
Vibration (vī-brā′shŭn)
Villi (vĭl′ī)
Vitamin (vī-tăm′ĭn)
Vitreous (vĭt′rḗ-us)
Vocal (vō′kăl)
Volatile (vŏl′ȧ-tĭl)
Volt (vōlt)
Volta (vôl′tȧ)
Voltage (vōl′tāj)

Warp (wôrp)
Watt (wŏt)
Windlass (wĭnd′lȧs)
Woof (wo͞of)

INDEX

Note to Student. In using this index bear in mind the following facts: (*a*) all numbers refer to pages; (*b*) an italic number (*54*) indicates that there is an experiment on that page; (*c*) a number followed by an asterisk (167*) indicates the presence of an illustration; (*d*) the index does not, as a rule, cover references to entire problems or units. For such references turn to the table of CONTENTS.